FAIRCHILD'S GROWING BEYOND EARTH

A CITIZEN SCIENCE PROJECT IN PARTNERSHIP WITH NASA

Year Two Evaluation Report
2017-2018

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Growing Beyond Earth
Year Two Evaluation Report

2017-2018

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I. Executive Summary

During the school year of 2017-2018, Fairchild Tropical Botanic Garden (Fairchild) implemented the second 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 assessing project outcomes using data collected between September 2017 and May 2018. This report's findings and accompanying recommendations inform next year's project implementation and evaluation activities.

Evaluation results indicate that Growing Beyond Earth has had a another successful year of implementation—from both an implementation and outcomes perspective. GBE continues to generate evidence of positive outcomes for students, NASA, and teachers. Overall, evaluation results are consistent with last year and provide further evidence to support the results initially identified last year. Results continue to be consistent across the various data collection methods and across participant groups.

During this second year of implementation an estimated 5,550 middle and high school students in 117 schools participated under the guidance of 135 teachers and Fairchild project staff.

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

1. GBE participation numbers grew.
2. GBE continued to expand and enhance its unique design.
3. Teachers continued to be engaged and satisfied with GBE.

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

1. Students had an authentic STEM research experience.
2. Students increased positive attitudes towards STEM.
3. NASA benefitted from Growing Beyond Earth student research.
4. Teachers improved their STEM instruction.

Evaluation results provide continued evidence of student outcomes:

- Engagement in authentic STEM experiences
- Understanding of, and hands-on experiences with, science practices (NGSS[1])
- Understanding of, and connections to, plants
- Applications of "book learning" to real world settings
- Connections between students' self-image and science

Additionally, results point to the increasing value to NASA: GBE students have become NASA plant research partners as NASA continues to see "clear benefits" from GBE research and "make decisions based on GBE data."

[1] NGSS: Next Generation Science Standards

II. Evaluation Activities

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 continued to address both the formative and summative evaluation questions (below). The results presented in this report emerged from the analysis of data collected between September 2017 and May 2018.

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 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 including: project products and records, focus groups, interviews, observations, and online surveys. Additional details on the data collection activities can be found in the Appendices.

Data Analysis: The findings presented in this report represent a synthesis and triangulation of all data collected during year two. Descriptive statistics were calculated for quantitative data. Qualitative data were analyzed for themes and other responses of interest. Comparisons to last year's evaluation results as well as assessment of meaningful differences between subgroups was conducted (academic level and student gender). Meaningful differences, when present, are reported.

III. Evaluation Results

This report presents the key synthesized evaluation findings. Much more detailed results, including numerous graphs, are located within the Appendices, specifically:

- PEAR Student Assessment Results
- Teacher Survey Results
- Participating Teacher Characteristics
- Classroom Implementation Summary

Outcomes Finding 1: Students Had an Authentic STEM Research Experience
Last year's evaluation results indicated that students participating in GBE have an authentic STEM research experience. As presented throughout this report, results from this year further confirm this finding.

The NASA funding source for GBE defines an authentic STEM experience as meeting at least three of the following criteria. As demonstrated below, GBE meets all five criteria.

1) *Features real-world STEM content*: GBE students are engaged in plant research that is used by NASA.

2) *Conducted in a real-world STEM setting*: GBE students conduct their research in a grow chamber designed by Fairchild that is analogous to the *Veggie* grow chamber used by NASA on the International Space Station (ISS).

3) *Directly participates in scientific practices:* GBE students closely follow specific GBE plant research protocols and Fairchild Challenge activity guidelines that directly correspond to the eight NGSS Science Practices:
    1. Asking questions
    2. Developing and using models
    3. Planning and carrying out investigations
    4. Analyzing and interpreting data
    5. Using mathematics and computational thinking
    6. Constructing explanations
    7. Engaging in argument from evidence
    8. Obtaining, evaluating, and communicating information

4) *Involves scientists and engineers as role models or mentors*: Students interact in-person or virtually with NASA and Fairchild scientists.

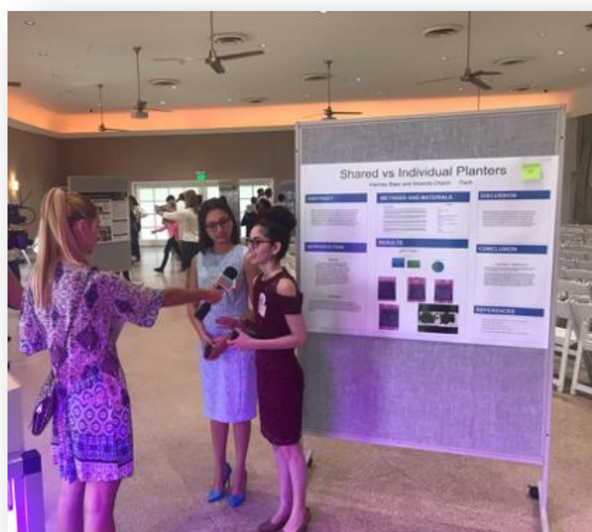
5) *Involves participants in collaborative project work*: All GBE students work collaboratively with other students to carry out GBE research activities and produce Fairchild Challenge submissions.

Students are aware that their participation in GBE is “real research” as opposed to “make work” science activities for a school assignment. They are aware that NASA is using their student data to directly support NASA research activities. Student and teacher interview data indicate that students comprehend the relevance and utility of their GBE research—they see themselves as research partners with NASA scientists.

> “We are doing something for the future, that’s the beauty of GBE.” GBE student
>
> “ The results of our work will actually be used.” GBE student
>
> “Students can help NASA.” GBE student
>
> “We now know how to do research.” GBE student
>
> “GBE is something that is real, not textbook science, not a cookie cutter experiment. Students actually act like a scientist.” GBE teacher

Participation in GBE appears to address developmental needs for adolescents which may be an important factor contributing to the level of student engagement in GBE. The Search Institute has developed a Developmental Assets Framework that identifies 40 positive supports and strengths (grouped into eight categories) that young people need to succeed. With its emphasis on important authentic research and caring for plants, GBE may play a role in the categories of:

- Empowerment (“Young people need to feel valued and valuable”)
- Positive Values (“Young people need to develop strong guiding values or principles to help them make healthy life choices” such as caring and responsibility)
- Positive Identity (“Young people need to believe in their own self-worth and to feel that they have control over the things that happen to them” such as having a sense of purpose)

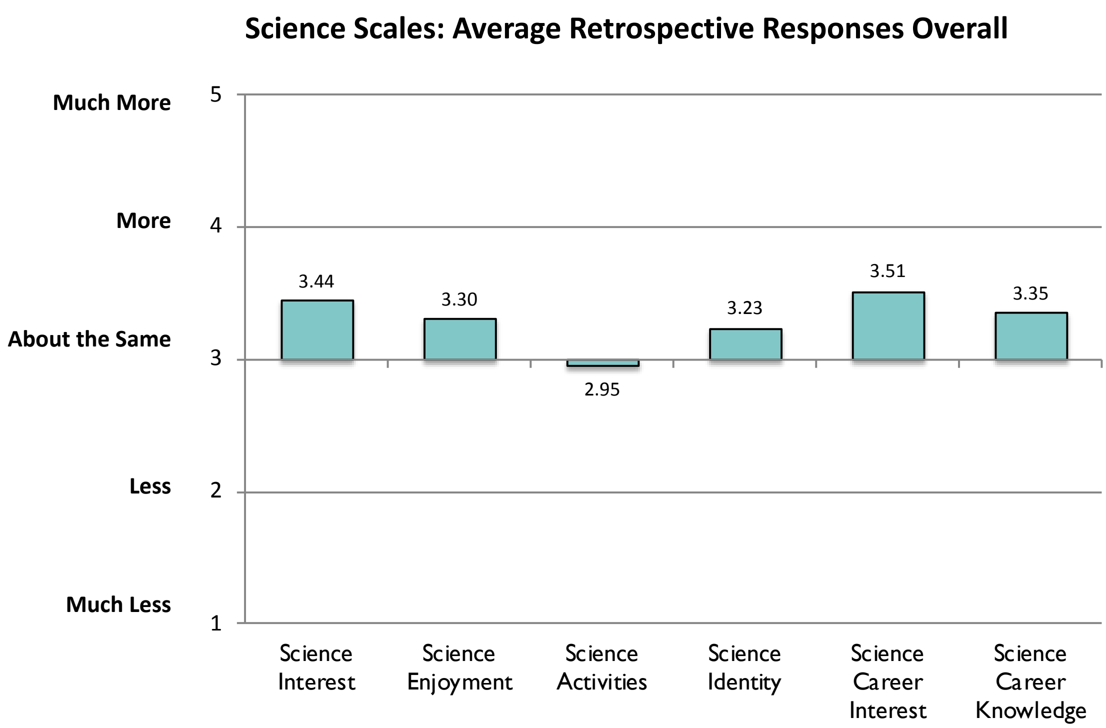


Outcomes Finding 2: Students Increased Positive Attitudes Towards STEM
(For more details, refer to *PEAR Student Assessment Results* and *Teacher Survey Results* in the Appendices.)

This year's evaluation provided further evidence of student STEM-related outcomes. A sample of 217 middle and high school students who participated in both the Fall and Spring GBE research trials completed a national STEM survey[2] including the following scales:

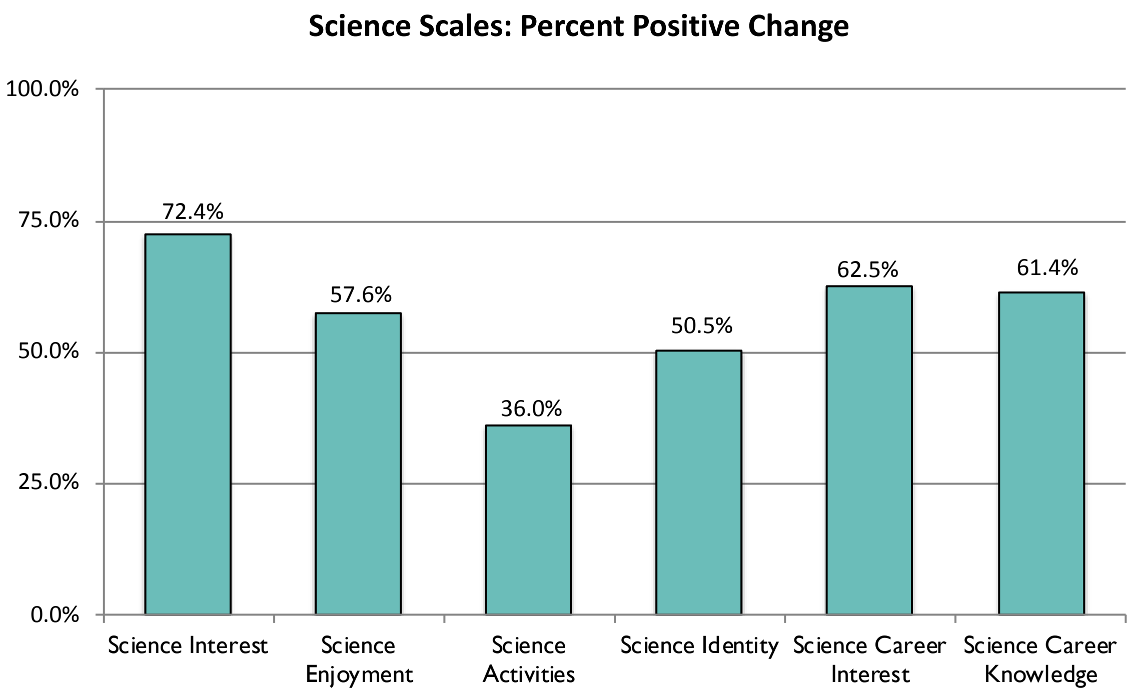
- Science Interest: How interested and enthusiastic a student is about science and science-related activities
- Science Enjoyment: How much a student enjoys participating in science-related activities
- Science Activities: How often a student seeks out science activities (such as reading a book about science, going on the internet to watch science -related videos, etc.)
- Science Identity: Students' perceptions about themselves as a "science person" (recognition) as well as how able they feel they are to do science (capability)
- Science Career Interest: How motivated a student is to get a career in science
- Science Career Knowledge: How knowledgeable a student is about obtaining a career in science

Overall, GBE students reported statistically significant gains on items relating to Science Interest, Science Enjoyment, Science Identity, Science Career Interest, and Science Career Knowledge ($p < 0.05$). No significant change was observed in ratings of STEM Activities.



[2] Permission to use the Common Instrument Suite (CIS) was obtained from The PEAR Institute at Harvard Medical School and McLean Hospital.

Overall, 72.4% of the students reported positive gains in Science Interest, 57.6% in Science Enjoyment, 36% in Science Activities, 50.5% in Science Identity, 62.5% in Science Career Interest, and 61.4% in Science Career Knowledge.

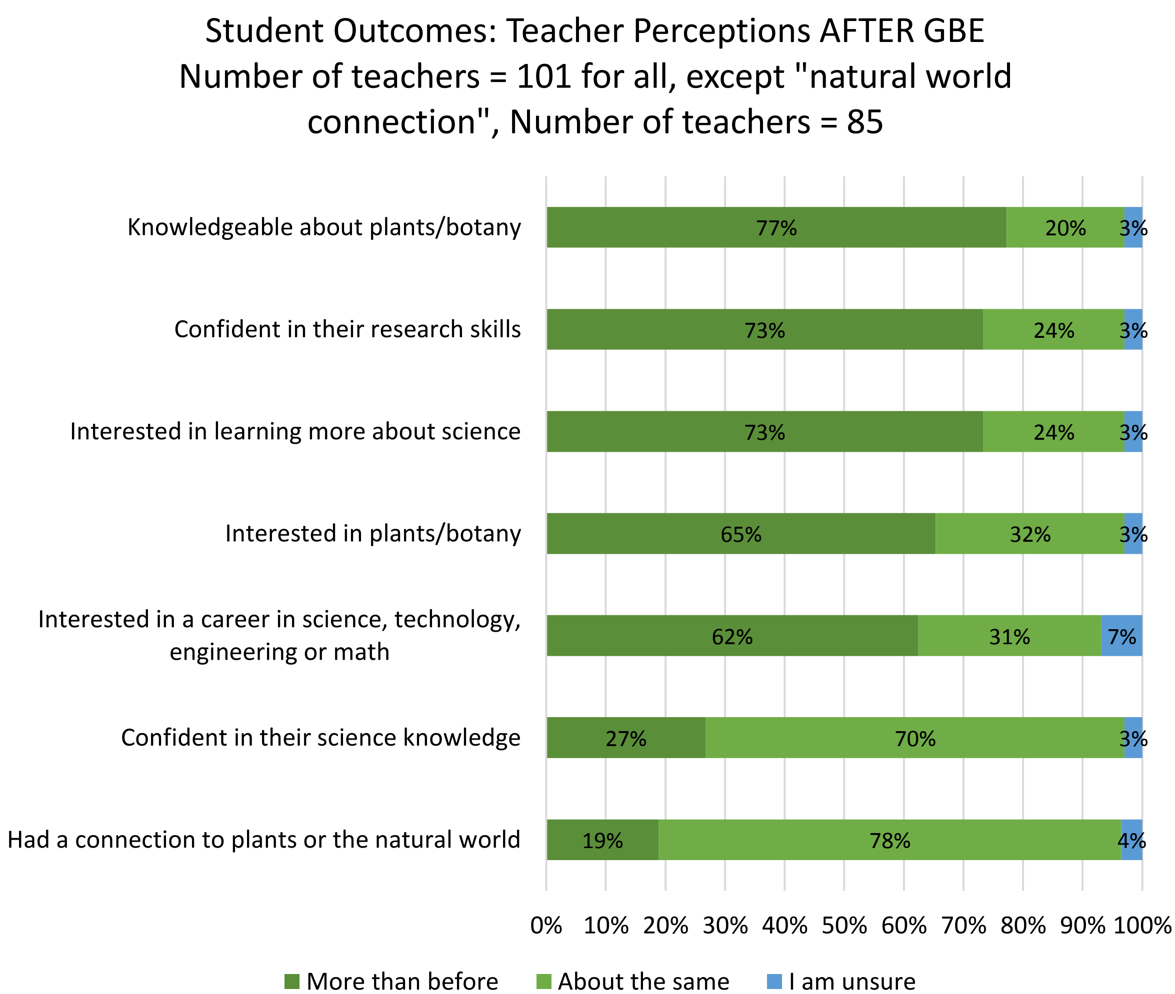


Additionally, results were analyzed comparing various subgroups:

- Gender: No statistically significant differences were found between GBE girls and boys.
- Grade level: Only several statistically significant differences were observed between the grade level groupings of Middle School, High School, and BioTech[3]:
    - BioTech students reported statistically significantly higher gains in Science Activities than Middle School students ($p<0.05$).
    - BioTech students reported significantly higher gains in Science Identity than both Middle and other High School students ($p<0.05$).

[3] BioTech students attend a botany focused high school program and participate in a more intensive GBE experience.

The graph below depicts teachers' perceptions of students' STEM-related knowledge and attitudes after GBE participation. A majority of teachers reported that their students increased STEM knowledge, interest, and confidence—with the exceptions of confidence in science knowledge and connections to the natural world[4]. Similar to last year's results, across all items, middle school teachers perceived a slightly higher level of change as compared to high school teachers' perceptions of student changes.



With one notable exception, these student and teacher survey results are consistent with analysis of interviews conducted by the evaluator during observations in GBE classrooms and at GBE-related events. In interviews with teachers and students, an increased connection to the plants students were growing was frequently mentioned as a characteristic of students' GBE experience—particularly with middle school students.

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[4] Connections to plants or the natural world is a new item that was not included in last year's teacher survey.

In their own words, teachers describe changes in their students as a result of GBE participation:

Stronger Science Practice and Research Skills

The experience of being able to see, harvest and measure the grams of a plant has been a learning experience for most students. A majority have never been exposed to any agricultural experience much less understand how it goes from plant to grocery store. Also, that this is used as research and that their data is important is a unique experience for them.

Students have become more comfortable implementing science protocols as well as gathering and analyzing data. They have learned to find anomalies in their data. One group found that another groups' data was much different. They investigated and discovered that the group had measured in inches instead of centimeters. The students were able to problem solve and self-correct.

They now understand how to complete Excel data sheets and how to convert data into graphs. They also understand the importance of a controlled experiment much better than before. They see the importance of replication and how it applies to experiments.

Increased Confidence and Positive Attitudes towards STEM

Even with my eighth grade boys that act like they're so cool and they're not interested in doing anything. They were interested … they wanted to water the plants or to do the measurements … and when we got the first tomato, they wanted to try some.

Students had tremendous growth in maturity level in terms of responsibility, commitment to something bigger than self, and ability to work as a team.

They became more motivated. Even students who don't always show up for class came on the day they were assigned to check on and care for the plants. Many of those students now offer to work in my garden. Students want to grow year-round under the lights.

Increased Interest in Botany

> *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.*
>
> *The fact that they've never grown anything from seed. They were just like, wow, this is so cool. Especially here in the city most of them live in condos and apartments.*
>
> *My students have found that they love botany and ask me for extra seeds to grow plants at home. They share what we learn with their families.*

Regional Science Fair Entries: A stated outcome of GBE is an increase in GBE-related regional science fair entries. It has been very difficult to collect data on this outcome. Based on evaluator observation of entries to the 2018 South Florida Regional Science and Engineering Fair there were six entries that were directly related to the GBE research protocols and an additional four entries that were "inspired by" GBE (i.e., related to growing food in space). A similar number of students submitted entries last year.

Outcomes Finding 3: NASA Benefits from Growing Beyond Earth Student Research

In this second year of full scale GBE implementation NASA staff report that there are "clear benefits to NASA that are becoming more and more apparent." During interviews, NASA staff recounted how GBE students' research has opened new doors for NASA's plant research in terms of plant varieties and growing techniques and that NASA scientists "make decisions based on GBE data" and "because of GBE NASA makes better, more informed decisions."

GBE students have become research partners with NASA scientists as they test numerous plant varieties under a wide range of conditions identifying hardy crops for further testing by NASA scientists.

> *[Based on GBE student research], we've narrowed down the crop list to the top five that have been identified each year. And we're putting those through our more rigorous testing scenario and we're actually going to fly at least two [in ISS] in the next month or so. And these are plants that we would probably have never looked at because there's so many potential crops out there.*

In year one GBE students identified a harvest technique for leafy greens that enables multiple harvests from the same plant and that technique has now been put into practice on the International Space Station (ISS).

> *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 students have identified additional ideas for how to best grow plants in space—such as in large pots rather than individual pots—NASA intends to further test these ideas.

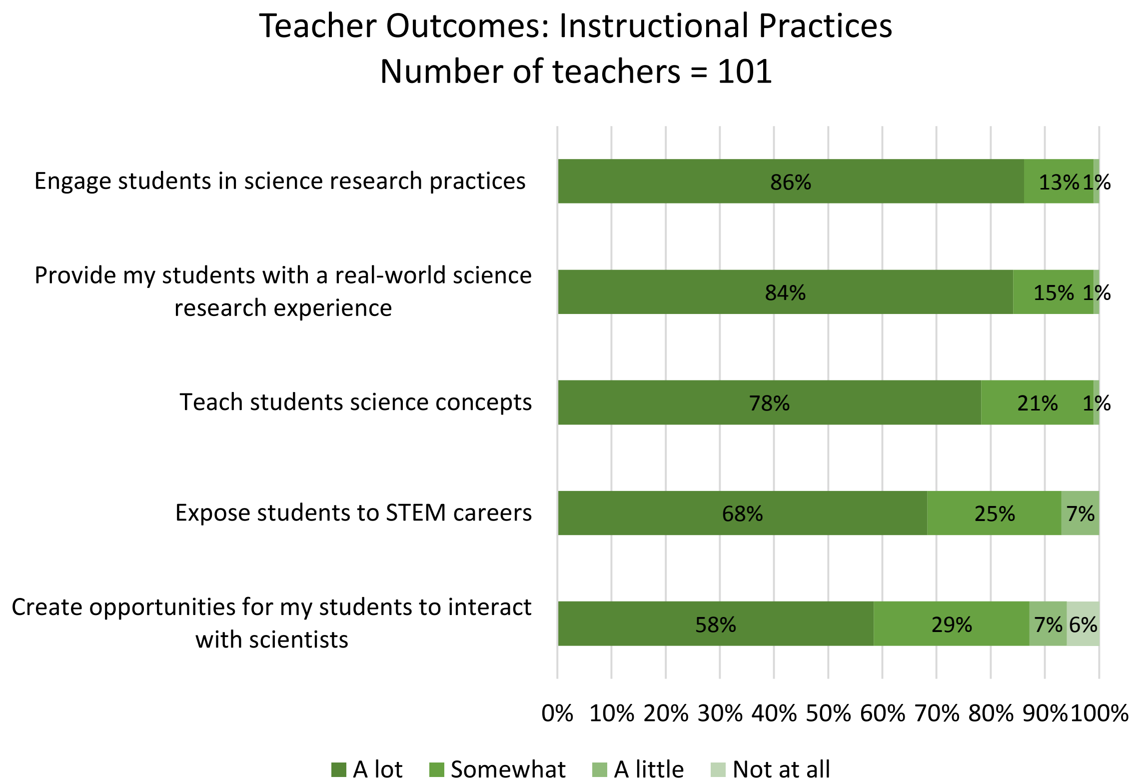
> *There was one group of GBE students that was talking about combining the root zones in one pot as opposed to separate pots. I was very impressed with their work and we're thinking about how can we test this in our system.*

Additionally, NASA staff have begun to present the GBE project at national and international conferences and to integrate GBE student research into their articles for peer-reviewed research journals.

Outcomes Finding 4: Teachers Improved Their STEM Instruction
(For more details, refer to *Teacher Survey Results and Classroom Implementation Summary* in the Appendices.)

As indicated in the graph on the following page, Growing Beyond Earth continued to enable teachers to provide unique, valuable instructional experiences and to strengthen their own skills and knowledge**.** Consistent with last year's results, <u>engaging students in science research practices and real-world science topped the list of instructional enhancements possible through GBE</u>.

Additional instructional benefits reported by teachers included engaging with the FIU university community, providing leadership opportunities, and promoting team work among the students. There was no meaningful difference between middle and high school teachers' responses.



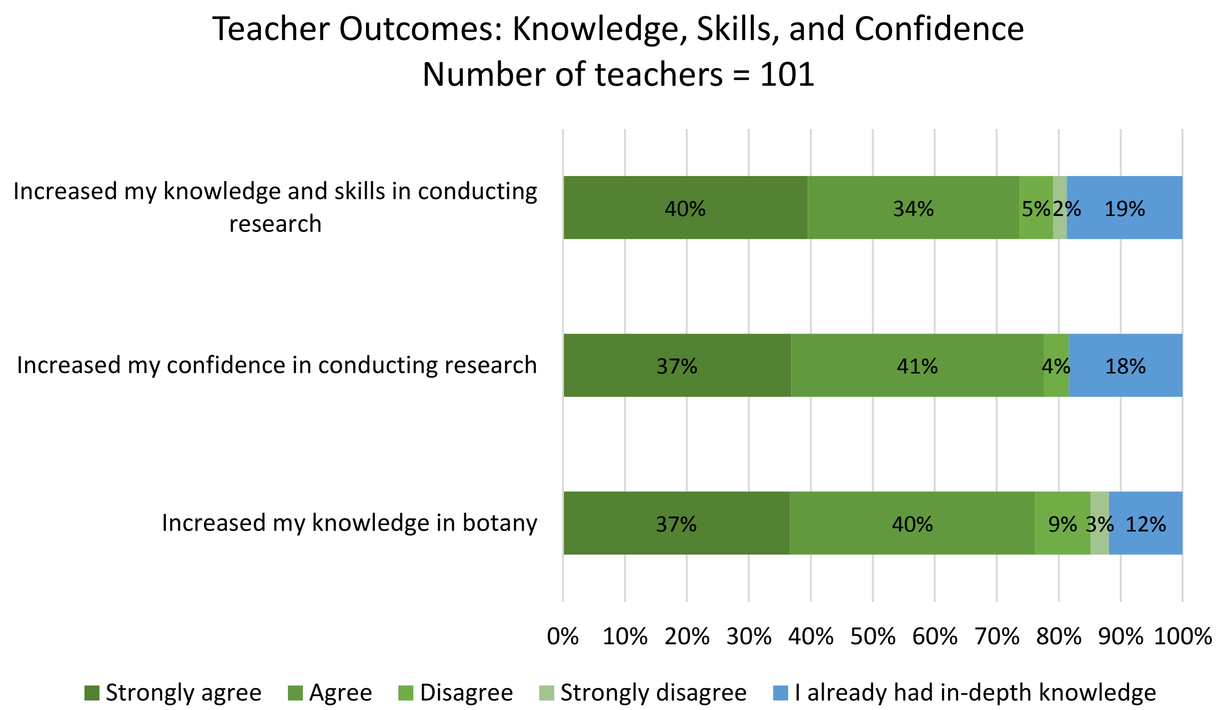
Classroom Implementation

Teachers integrate GBE into their instruction is a wide variety of ways ranging from formally incorporating GBE as part of their graded instruction for one or more classrooms to engaging interested student volunteers in GBE activities during home room, lunch, class time, afterschool, or in extracurricular clubs. Additionally, teachers engage students in GBE-related tasks in a variety of ways. Some rotate tasks amongst students, some have students work in teams, some assign specific roles to specific students.

- 73% of teachers required all of their students in one or more classes to participate in GBE activities. This is a slight increase from last year (62%).
- Most teachers integrated GBE into regular classroom activities at least occasionally; with 68% integrating GBE often. There was a 22% increase in teachers who integrated GBE often as compared to last year (46%).
- Similar to last year, most teachers (61%) implemented GBE during classroom time.
- In a majority of classrooms (60%), all students spent about the same time engaged in GBE activities. In comparison, last year, 39% of teachers reported that all students spent the same amount of time. This result may be due to more teachers making GBE a required student activity.
- Similar to last year (78%), most teachers (78%) used GBE activities to assign grades or extra credit for students. Middle school teachers were slightly more likely than high school teachers to assign grades for GBE.
- 32% of teachers reported collaborating with another teacher on GBE activities.
- 85% of teachers reported that students analyzed GBE data in addition to collecting data.

Teacher Outcomes

Consistent with last year's results, teachers reported increases in their own research and botany knowledge, skills, and confidence as a result of participating in GBE. There was no meaningful difference between middle and high school teachers' responses.



Findings: Project Implementation

Implementation Finding 1: Participation numbers grew as GBE continued to engage a diverse group of students and teachers in Miami-Dade County and beyond.
(For more details, refer to *Participating Teacher Characteristics* and *Classroom Implementation Summary* in the Appendices.)

Teacher Participation and Characteristics

- 135 teachers participated during 2017-2018 as compared to 110 last year.
- Teachers represented a total of 117 schools—72 middle schools and 45 high schools. Last year, 97 schools participated. This year 18 schools outside of Miami-Dade County participated.
- Teacher Academic Subject Areas: General and Biological Sciences continue to be the courses most frequently associated with GBE participation.

- Teacher Grade Levels: Middle school teachers continued to account for the majority of participating teachers (57% middle, 39% high, and 4% who teach both).
- School Type: The majority of participating schools continued to be public schools. The percentage of public schools decreased this year by 9% (from 65% to 56%) and the percentage of charter schools increased by 8% (from 13% to 21%).
- Teacher Background: A typical teacher participating in GBE has a Bachelor's degree and has been teaching for more than 10 years.
- Teacher Demographics: More than 75% of participating teachers were female and nearly half were Hispanic.

Student Participation and Characteristics

- 107 of 135 participating teachers provided classroom implementation data and reported that 4,426 students actively participated in GBE; 1,432 in high school and 2,994 in middle school. This is most likely an undercount of student participation as only 80% of participating teachers reported student numbers. Extrapolating from the data, a reasonable estimate is that approximately a total of 5,550 middle and high school students participated based on an average of 41/teacher.

- An average of 41 students participated per teacher—with a minimum of 2 and a maximum of 143. Last year an average of 33 students participated per teacher.
- As was true last year, most teachers implemented GBE in multiple grade levels.
- Overall, student demographics were very similar to last year.
  - An equal number of female and male students participated: 47% males, 52% females.
  - The racial and ethnic breakdown of students was estimated to be: 63% Hispanic; 19% Black; 14% White, non-Hispanic; and 4% Other.
  - An average of 6 students with an IEP and 4 LEP students participated in each classroom, ranging from 0 to 75 per teacher.

Implementation Finding 2: Growing Beyond Earth continued to expand and enhance its unique design.

During this second year of full scale implementation, Fairchild added several new components to GBE including:

- Addition of student-designed research trials and research posters
- A student research symposium resembling a typical academic research poster session
- Student presentations at a professional horticultural conference
- Online videos demonstrating GBE research protocols
- A downlink to the International Space Station so that a sample of GBE students could interact directly with ISS astronauts
- A new NASA badge for educators was developed for GBE

Comparing GBE to Other STEM Programs

A recurring theme in the data collection is the extent to which GBE is unique. Below is a selection of teacher quotes[5] that reflect the variety of ways that GBE is different from other STEM programs. The most common response was that GBE enables students to engage in long-term, meaningful, real-world research.

a. *GBE is at another level because student data contributes directly to NASA research.*
b. *As a citizen science project with support from professional scientists GBE offers exposure and participation in current scientific research.*
c. *The students love the fact that they are working with NASA. I have a special education student whose dream is to work with NASA someday and he motivated everyone around him. He stated, "We need to figure out good stuff to grow because I will be in space eating it one day."*
d. *GBE is a much more personal project, where not only are students performing hands-on activities, but also naming their crops, watching their plants grow, and feeling like they are part of something bigger in helping NASA in their mission.*
e. *This STEM activity included plants which they loved watching grow and were sad when they saw them die. There seemed to be more emotion involved in this STEM activity than in others.*
f. *GBE is a STEM activity that is based on life science. Most outreach STEM activities focus on Physics, Robotics, etc.*

[5] Quotes have been slightly edited for consistency in format only and are listed in no particular order.

g. *GBE is always very fulfilling for the students because it's not just a one-time experiment. The fact that it runs for about 5 weeks makes it a* <u>*long-term learning experience*</u> *from which they can later apply skills learned to other experiments.*
h. *GBE is very* <u>*student centered*</u>*.*
i. *It's a long-range project so it requires patience and doesn't provide instant gratification - which is hard for high schoolers!!!*
j. *The students felt empowered because it was* <u>*data being used in real-life applications*</u>*.*
k. *Students particularly enjoyed that it is being applied to real science with real impact. It was also different in that they got the opportunity to actually* <u>*develop a whole research project start to finish*</u>*.*
l. *The* <u>*math application involved in this activity is different*</u> *than other STEM activities. It's not as intimidating. It's* <u>*more analysis and finding patterns rather than doing calculations*</u>*.*
m. *The students were able to work with a greater level of data. The protocol also* <u>*taught them about experiments above the level that they have seen*</u>*.*

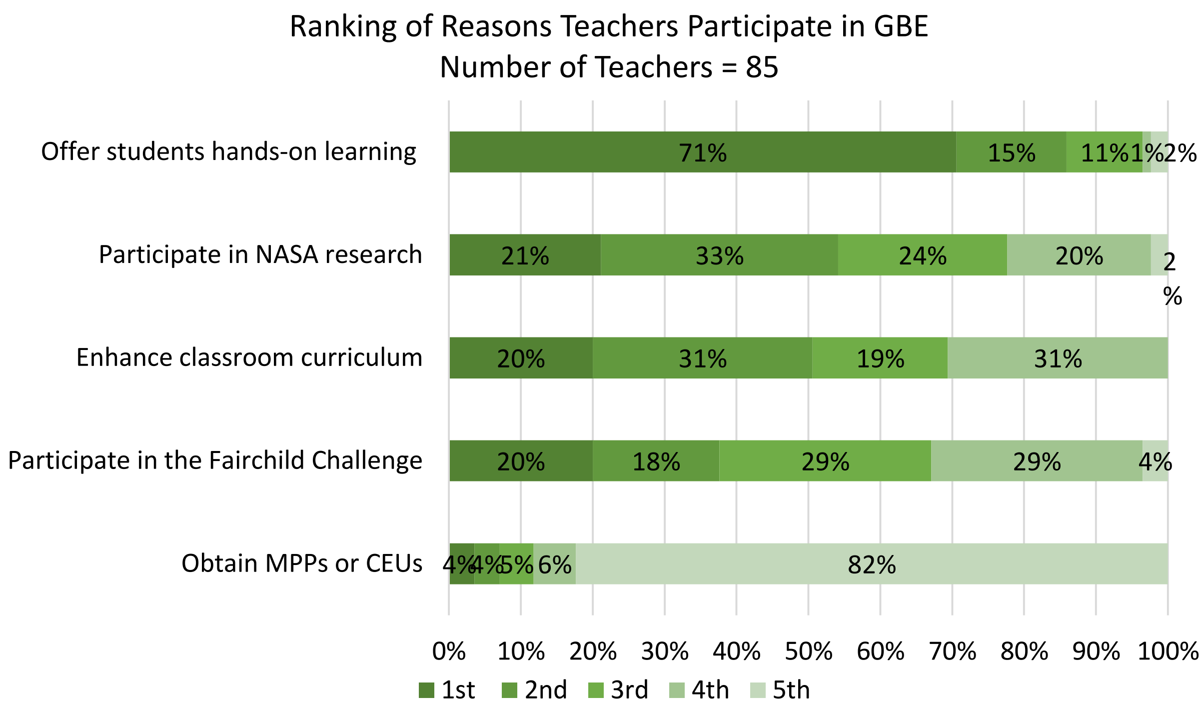
Two additional unique aspects of GBE are:

- <u>The adaptability of GBE to a wide variety of instructional settings</u> which facilitates teacher participation. Although the GBE plant research protocols are very structured and must be followed closely, teachers have wide latitude to engage students in completing the protocols according to their instructional needs and preferences. Variation includes subject areas (e.g., art to science), number of students participating, manner in which students participate (e.g., teams, roles, etc.), part of the school day GBE activities take place, duration of GBE engagement, etc.

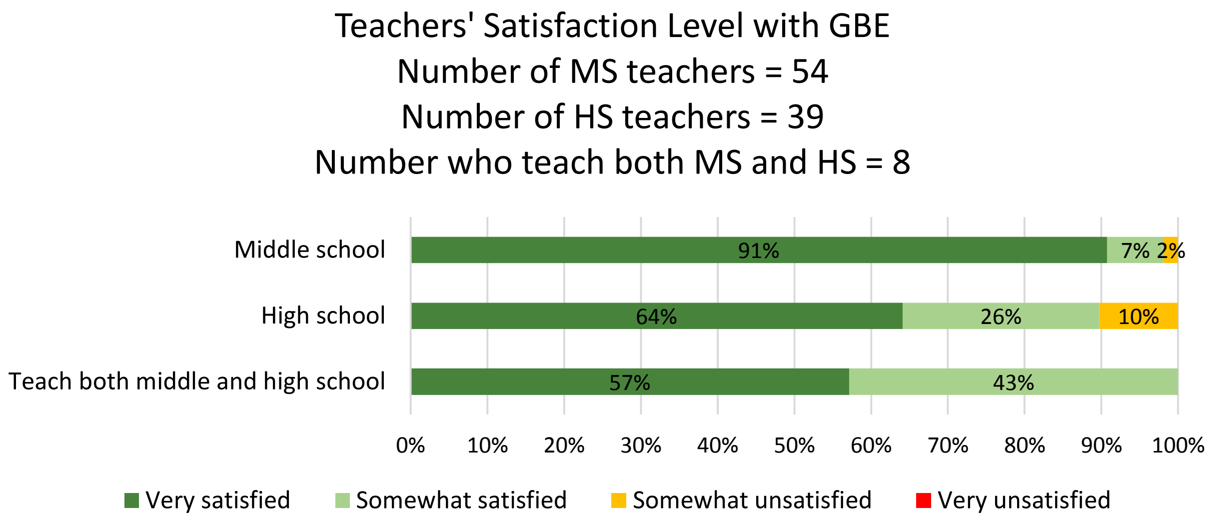
- <u>The ability to engage a large number of students in an authentic research experience</u>. Traditionally, students have engaged in authentic research experiences through internships at local universities or businesses which can only serve a small number of students each year as opposed to the more than 5,000 students participating in GBE this past school year.

Implementation Finding 3: Teachers continued to be engaged and satisfied with GBE.
(For more details, refer to *Teacher Survey Results* in the Appendices.)

Teachers were provided, and asked to rank, five possible reasons regarding their decision to participate in GBE. The primary reason a large majority of teachers participate is to be able to offer their students a hands-on learning experience. Participating in NASA research and enhancing the classroom curriculum were also important reasons teachers chose to participate—ranking either 1 or 2 for a majority of teachers. Very few teachers participate in GBE to earn professional development credits (MPPs or CEUs). There was no difference in responses between middle and high school teachers.



Overall, the majority of teachers (76%) were very satisfied with GBE—representing a 13% increase from last year (63% in year 1). As indicated in the graph on the following page, middle school teachers had slightly higher levels of satisfaction than high school teachers.



Additionally, the majority of teachers reported that they are very likely to participate next year, submit an entry to next year's Challenge, and recommend GBE to a colleague. Similar to the overall satisfaction responses reported above—overall, slightly more of this year's respondents, particularly middle school teachers, reported being very likely to continue participation and recommend GBE.

A majority of this year's teachers (60%) also participated in GBE last year. Additionally, 74% of teachers participated in the Fairchild Challenge (Challenge) in prior years.

Recommendations and Conclusion

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.

Overall this second year of full scale implementation and expansion appears to have gone smoothly and the recommendations provided by teachers, NASA, students and the evaluator represent opportunities for continual quality improvement and enhancement. Recommendations for improvement reflect a project that has made good progress addressing any implementation challenges from last year.

Recommendation Themes

- The addition of student-designed research proposal, trials, and research posters this year should be continued. Teachers as well as NASA staff perceive these GBE activities as an enhancement to GBE research activities and student learning.
- Continue to explore ways to increase the interactions between students and scientists including informing students of how NASA is using GBE data.

- Consider Spring testing schedules when designing GBE protocols and Challenge entries. In the lead up to, and during, Spring testing it is very difficult for teachers and students to participate in GBE-related activities.

<u>Teacher Recommendations</u>
At least 10% of the 101 teachers who completed the survey made the following suggestions, with the items at the top of this list being the most common:

- Provide more resources to teach students about STEM careers
- Provide more opportunities to engage with scientists
- Provide more detailed instructions, with smaller training groups and opportunities for digital trainings (e.g., using webinars or video conferencing software)
- Extend the timeline so that there is more time to complete the Challenge
- Provide more professional development on topics such as: incorporating GBE into the classroom, botany, and research skills
- Provide more resources to implement GBE (e.g., equipment, data collection templates, etc.)
- Prior to GBE registration, provide more clarity regarding the materials supplied by Fairchild and those that teachers need to provide
- Offer fieldtrip opportunities to Fairchild that include time to meet a scientists (botanists, NASA) and to learn about STEM careers

The following suggestions were made by only one teacher; however, they may be worthwhile for GBE staff to consider:

- Create a checklist to organize multiple submissions
- Create opportunities for students to do multiple trials for comparisons
- Make the poster board an optional part of the submission (i.e., 200 points for the data and 100 points for the poster)
- Encourage composting at the school by using compost instead of chemical fertilizers
- Share written notes regarding changes in protocols from prior years (e.g., splitting the fertilizer)
- Make the tubes with the seed names easier to read and have labels for the pots
- Allow teachers who have participated in GBE in prior years to do a partial training day
- Provide some type of recognition for teachers and students who complete the GBE activities but do not submit an entry to the Challenge.
- Consider adding GBE-related technical drawing as a component of a Challenge (i.e., drawings as part of the plant growth documentation process).

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 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.