

EVALUATING THE IMPACT OF PROFESSIONAL SCIENCE INVOLVEMENT ON
STUDENTS AT THE MARINE ACADEMY OF SCIENCE AND TECHNOLOGY AT
FLORIDA INTERNATIONAL UNIVERSITY BISCAYNE BAY CAMPUS

by

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ABSTRACT

I teach at The Marine Academy of Science and Technology at Florida International University in Miami, FL. As a dual enrollment, environmental studies high school science magnet, my students are required to take six science credits beyond FL's state minimum to satisfy curriculum demands. In response to this, my upperclassmen have expressed fatigue and a growing disinterest in science, technology, engineering and math (STEM) courses. Recognizing the need for promotion of enthusiasm in STEM, the purpose of this research was to investigate the impact of professional science involvement on my 11th and 12th grade honors bioscience students. I hypothesized that through participation in real-world science, students would be able to see the relevance behind their instruction and change their attitudes toward STEM courses and careers.

Treatment in this study consisted of student participation in a citizen science project, *Growing Beyond Earth (GBE)*, offered by David Fairchild Tropical Botanic Gardens and the National Aeronautics and Space Administration Agency (NASA). *GBE* was a competition-based exploration of NASA's veggie unit that gave students a chance to submit their findings to project organizers to be evaluated for implementation on the International Space Station (ISS). As a part of *GBE*, students built and maintained a plant atrium that mimicked conditions on the ISS during a 90-day growth trial. Students were responsible for monitoring plant health and watering regimes, managing biometric data both digitally and paper-based, harvesting plant tissues, and synthesizing research proposals from their work. Contact time for *GBE* varied based on the activity and is broken down in the accompanying logic model (See Table 2).

Student attitudes, academic performance and retention in STEM were evaluated in response to treatment. Attitudes were measured using the Professional Science Impact Instrument (PSII), academic performance through the Science Concept Quiz (SCC), and STEM career retention was measured through the Student Interest Inventory (SII). I developed all instruments for the purpose of evaluation in this action research project and they do not pull from previously existing instruments. Analysis of the SCC returned statistically significant learning gains posttreatment, while results of the PSII and the SII were mixed.

INTRODUCTION AND BACKGROUND

Project Background

School Demographics

I teach at The Marine Academy of Science and Technology at Florida International University Biscayne Bay Campus (MAST@FIU) in North Miami, FL. MAST@FIU is a dual enrollment environmental studies high school science magnet that saturates its students with science and math courses well beyond graduation requirements in these areas. According to the Florida Department of Education, students only need a total of four math credits, one of which can be completed at the middle school level (pre-algebra), and three science credit hours to graduate with a high school diploma. MAST @ FIU students, however, are required to take eight science and four math credit hours (not including pre-algebra) to graduate. Students are expected to take a minimum of two science courses per year and one math course per year, with courses offered at the honors, advanced placement, and college levels. This is an important anecdote because it serves to illustrate the need to maintain student interest levels in science courses throughout the entirety of their pre-collegiate coursework, considering the impact that attitudes can have on life-long learning outcomes.

Currently, there are 307 students enrolled in MAST's rigorous program, many of whom make long trips on public transportation systems from inner city areas to attend the school (M. Welker, personal communication, December 10, 2016). Underrepresented minority students account for more than 80% of the student population, and more than three fourths of the student body receive free or reduced lunch from the state (M. Welker,

personal communication, December 10, 2016). Most of the students have parents whose first language is not English, and many will be the first in their families to attend college (M. Welker, personal communication, December 10, 2016). While MAST@ FIU BBC offers an amazing array of science, technology, engineering, and math (STEM) opportunities, being a teacher at this school has allowed me to gain insight into how students feel after receiving an early education that is heavily focused on STEM coursework. With such a heavy emphasis placed on the volume of coursework in science, upper-level students at MAST have increasingly expressed fatigue with science content and disinterest in related subject matter.

Teaching and Classroom Environment

Over the past four years, I have taught a variety of physical and biological science courses to grades 9 through 12. I have progressed in grade level instruction at the same rate as the first cohort of students admitted into MAST @ FIU BBC program. I currently teach 11th and 12th grade honors bioscience, which is essentially a curriculum-free course wherein I maintain control over what content to cover (See Table 1). Because I have a background in marine science field research and my education certification areas are in biology and chemistry, I developed a course that focuses on south Florida's ecology through the use of project-based learning (PBL).

Table 1
Honors Bioscience Course and Student Information (N= 83)

Class	Meeting Time	(N) total	Male	Female
Period 1	7:20 AM – 9:00 AM	27	15	12
Period 3	9:05 AM – 10:35 AM	27	16	11
Period 4	9:05 AM – 10:35 AM	29	18	11

In order to promote student engagement with their immediate environment, honors bioscience heavily utilizes hands-on, experiential, and field-based learning. As such, honors bioscience is a PBL course that emphasizes ecological content and ongoing research in South Florida and, in an attempt to spur further interest in STEM programs, aims to directly involve students in various aspects of professional science when possible. While I am extremely excited about getting my students to apply their knowledge of science in more practical, research-oriented scenarios, and for them to learn more about their immediate surroundings, they have expressed a detectable level of disinterest, which has prompted me to reevaluate how my students perceive my instructional strategies benefit them.

Research Purpose

The purpose of this classroom research is to investigate the impact of professional science involvement on my honors bioscience students at MAST @ FIU. In the context of this project, professional science is defined as science led by research scientists, agencies, or organizations and student participation with these groups might include activities such as data collection and interpretation through citizen science initiatives, student-designed experiments, and interactive lectures. Since my students have expressed feeling as though STEM courses have become more rhetoric than reason, I selected the *Growing Beyond Earth* citizen science project, offered through the David Fairchild Tropical Botanic Gardens and the National Aeronautics and Space Administration (NASA), to see if the opportunities to have their research translate into NASA protocol would change their sentiments. I hypothesized that I would be able to address any waning

enthusiasm for STEM by involving my students in professional science through this type of citizen science project; and that participation would positively influence other critical areas of their education simultaneously. In order to evaluate the impact that professional science involvement may have on students in my classes so as to make adjustments in my instructional strategies that improve my ability to foster student retention and performance in STEM studies and careers, I aim to answer the following questions:

Primary Research Question

- What is the impact of student involvement in professional science offered through Bioscience at MAST?

Sub Questions

- What is the impact on student attitudes toward science education?
- What is the impact on student academic achievement?
- What is the impact on student retention in STEM-related programs at MAST and beyond?

To assist me in quantifying the impact that professional science involvement had on my students, I recruited my principal to serve as an expert reviewer of the instrumentation protocols and my mother to serve as a resource for bouncing instructional ideas off of. My principal and my mother have more than 60 years of experience in education combined and, partnered with my committee chair and science reader, have provided me with insight to determine whether measures taken to evaluate treatment impact are plausible and valid.

CONCEPTUAL FRAMEWORK

In January of 2011, President Obama highlighted the need to encourage inventive thought in STEM-related fields and claimed that such thought would be critical to spurring further growth in America's economy and ensuring success for the future of the country (Obama, 2011). This ideology was further emphasized in a report that focused on the role that STEM education at the K-12 levels plays in facilitating such thought (National Economic Council, 2011).

Researchers (Eguchi, 2016; Kanter, 2010; Osborne, Simon, & Collins, 2003; Jones, Rasmussen, & Moffitt, 1991) have argued that deviations from traditional teaching methods in science in order to promote the necessary skills for success within STEM sectors must be made so as to incorporate community partnerships, integration of technological tools, and global perspectives through interdisciplinary approaches in highly collaborative, learner-centered communities that focus on learning problem solving skills. Eguchi (2016) explored the use of team, project-based learning in an international initiative, dubbed "RoboCupJunior," that aimed to educate youth participants in robotics technology. The competition was collaborative in nature and revolved around the need to design, construct, and program robots in a team setting that would later be tested in different competition "challenges." Eguchi (2016) found that participation in the RoboCupJunior competition increased interests in STEM content after evaluating participant interests before and after involvement in the competition. And, though some would argue that participants would more than likely have had a positive

pre-existing disposition to STEM content in the first place, the results still indicated a positive impact on participant interests in STEM fields regardless (Eguchi, 2016).

Around the turn of the 21st century, investigators (Osborne, Simon, & Collins, 2003; Department of Education, 1994) noted a marked decline in the number of young persons interested in pursuing careers in science. Osborne, Simon, & Collins (2003) even argued that the reduced number of students participating in science and mathematics courses and negative attitudes towards such subjects posed as a grave threat to the economic prosperity of any country. The decline noted in the previous body of research occurred simultaneously as the global demand for STEM workers increased sharply, a trend which continues today (National Academies, 2007). Sir Neil Cossons (1993) argued that the distinguishing characteristic of most modern societies is achievement in science and technology, and, that regardless of the influence on economic interests, the decline in interest in science remains a solemn concern for any society. With increased recognition of the economic utility and importance of STEM careers in our immediate and foreseeable futures, considerations of how to promote favorable attitudes towards science education and careers have been undertaken.

Klopfer's (1971) influential research on the affective behaviors in science education has contributed significantly to the understanding of how student attitudes can influence behaviors. Affective behaviors categorized by Klopfer (1971) include the following:

- the adoption of 'scientific attitudes;'
- the manifestation of favorable attitudes towards science and scientists;

- the acceptance of scientific inquiry as a way of thought;
- the enjoyment of learning experiences in science;
- the development of an interest in the pursuit of career in science or science-related work; and
- the development of interests in science and science-related activities.

Feelings, values, and beliefs held about science that may be an enterprise of science, school science, or the impact of science on society or scientists themselves are all considered to be components of attitudes towards science (Osborne, Simon, & Collins, 2003; Klopfer, 1971). Student behavior is seen as a product of intention, and, consequently, intention is seen as a collective byproduct of attitude towards a behavior and the subjective norm (Osborne, Simon, & Collins, 2003). Mental constructs and sub-constructs of students make quantifying attitudes difficult for educational researchers as variables unaccounted for in research might contribute more significantly to the observed phenomena.

To account for the degree of variability inherent in the contributing factors responsible for student attitudes in science, researchers (Koballa Jr., 1995; Woolnough, 1994; Piburn, 1993; Breakwell & Beardsell, 1992; Crawley & Black, 1992) have explored measurements for different components of attitude that have included aspects of self-esteem at science; anxiety toward science; value of science; enjoyment of science; nature of the classroom environment; attitudes of parents towards science; attitudes of peers and friends towards science; motivation towards science; perceptions of the science teacher; fear of failure in the course; and achievement in science. Recognizing that

behavior can be influenced by other strongly held attitudes than the attitudes that are actively taken under consideration for any given investigation, researchers generally strive to incorporate multiple modalities through which to measure the expressed feelings of students towards science and their behaviors in science (Osborne, Simon, & Collins, 2003).

Whitfield (1980) and Ormerod (1971) have explored student attitudes towards science by asking students to rank their preference of school subjects to use frequency or popularity of a response as a proxy to gauge students' attitudes toward the subject matter. Both authors noted that the fundamental issue with ordinal data is that the scale of measurement is relative to each individual survey respondent, and that the need to incorporate alternative evaluation techniques with such instrumentation is inherent in the limited conclusions one can draw from such variables.

Another evaluation tool for quantifying student attitudes in science are questionnaires that consist of Likert items. Items can be singular or scaled in nature and generally consist of a number of opinion statements that either reflects unfavorable or favorable attitudes toward science (Osborne, Simon, & Collins, 2003). In addition to Likert surveys, Woolnough (1994) notes the use of interviews to promote deeper, qualitative data-rich experimentation as a means to further explain and interpret findings on student attitudes toward science.

Student attitudes towards science have been shown by researchers (Osborne, Simon, & Collins, 2003; Whitfield, 1980) to vary with the nature of the specific science content. It is thought that the difference in attitudes towards different science subjects

stems from the relevance or utility of the information to students' lives (Osborne, Simon, & Collins, 2003; Whitfield, 1980). For example, students found human biology to be of particular interest because it addressed pupils' self-interest in their own concerns about their bodies and health, whereas the relevance of physical science was more difficult to identify (Osborne, Simon, & Collins, 2003). This finding is important because it suggests that students seek *utility* out of their science education.

Classroom environment is considered to be an important aspect of cultivating the desired affective behaviors of students. Classroom management is a skill that is explicitly taught in post-secondary education courses as it is generally seen as a significant determinant of attitude (Osborne, Simon, & Collins, 2003). Moreover, researchers have found that the use of varied and unusual instructional strategies correlates positively with attitudes toward science (Osborne, Simon, & Collins, 2003; Piburn, 1993; Myers & Fouts, 1992). This suggest that pedagogical practices can have a direct influence on attitudes and, consequently, behavioral outcomes.

METHODOLOGY

Treatment in this study consisted of student participation in a citizen science project, *Growing Beyond Earth (GBE)*, offered by the David Fairchild Tropical Botanic Gardens and National Aeronautics & Space Administration (NASA). *GBE* was a competition-based exploration of NASA's veggie unit that gave students a chance to submit their findings to project organizers to be evaluated for implementation on the International Space Station (ISS). The *GBE* challenge was one competition offered through the "Fairchild Environmental Challenge," which is described in greater detail in

later sections. As a part of *GBE*, students built and maintained a plant atrium that mimicked conditions on the ISS over the course of a 90-day growth trial. Students were responsible for monitoring plant health and watering regimes, managing biometric data both digitally and paper-based, harvesting plant tissues, and synthesizing research proposals from their work. The activities for *GBE* varied, and they are broken down in the accompanying logic model (See Table 2). I created multiple extension activities to the *GBE* activities, which are also reflected in the model below.

Table 2.
Logic Model for GBE Activities: Inputs (pg. 10-11), Outputs (pg. 11-12), and Outcomes (pg. 12).

<p>Inputs</p>	<p>Resources Needed</p>	<ul style="list-style-type: none"> • <i>Growing Beyond Earth</i> materials: <ul style="list-style-type: none"> a. Mandatory professional development training for teachers, 9/12/2016 b. Memorandum of understanding, NASA & David Fairchild Gardens, 9/2/2016 c. <i>GBE</i> protocol and datasheets d. Plant atrium: LED lights, automated timer, 4 polystyrene plastic walls, 1 sheet of polycarbonate roof paneling, 1 hygrometer, two shelves and four legs with accompanying attachment clips, watering tray and pad e. Cultivars: randomly assigned <i>GBE</i> cultivars- 75, 77, and 88, Florikan fertilizer mixture (14-4-14, T180 50% and 14-4-14, T100 50%, plus 14-4-14 T180/T100 2 g/L calcium nitrate), potting soil, turface, nine square plastic plant pots f. Volumetric containers for watering g. Paintbrushes for fertilization h. Rulers for biometric data collection i. Scale for mass at harvest • Additional materials for <i>GBE</i> extension activities: <ul style="list-style-type: none"> a. Internet access
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Inputs Cont'd		<ul style="list-style-type: none"> b. Research database access c. Microsoft PPT and Word d. Google documents e. Projector and desktop/laptop access f. Activity sheets: <i>GBE</i> annotated bibliographies, research proposal writing, MS Excel data visualization
Outputs	Activities	<p>Treatment:</p> <ul style="list-style-type: none"> • 90-day <i>GBE</i> growth trial student activities (September – December, 2016): <ul style="list-style-type: none"> a. Plant atrium set-up, maintenance, and break-down b. Cultivation of <i>GBE</i> 75, 77, and 88 from seeds to harvest c. Establishing watering regimes d. Daily plant health and environmental monitoring e. Weekly biometric calculations f. Weekly digitization of data sheets g. Research presentation to Fairchild and NASA reviewers (by invite from reviewers only) • <i>GBE</i> extension student activities: <ul style="list-style-type: none"> a. Massa <i>et al.</i> paper analyses and presentations (September, 2016) b. Annotated bibliographies (September – October, 2016) c. MS Excel data visualization (November, 2016) d. Research proposal writing, 1-3 (Sept., Dec. of 2016 and Jan.-Feb. of 2017) <p>Evaluation instruments:</p> <ul style="list-style-type: none"> e. Pretreatment/posttreatment administration in early September, 2016 and the end of February, 2017 <ul style="list-style-type: none"> i. Professional Science Impact Instrument (PSII) ii. Student Interest Inventory (SII) iii. Science Concept Quiz (SCQ)

Outputs Cont'd	People	<p>Lead researcher/teacher</p> <ul style="list-style-type: none"> • Graduate committee members: Walt Woolbaugh (advisor), LeAnne Yenny (science reader) • Graduate capstone project external advisors: Gayle Gunn and Matthew Welker • 11th and 12th grade honors bioscience students at MAST
	Products	<ul style="list-style-type: none"> • <i>GBE</i> cultivar harvest and digitized data sheets (Fairchild/NASA Google doc and MAST student Excel sheets) • Research proposals (2 to submit to Fairchild Gardens and NASA reviewers) • <i>GBE</i> extension activities submissions • AR capstone project data and findings
Outcomes	Short Term	<ul style="list-style-type: none"> • Establish baseline for student attitudes, career goals, and academic performance • Provide students with an inlet to citizen science
	Medium Term	<ul style="list-style-type: none"> • Foster process-based skills in scientific research • Facilitate positive learning communities
	Long Term	<ul style="list-style-type: none"> • Promote enthusiasm in STEM • Improve student academic performance • Increase retention in STEM fields • Enhance teacher awareness of student perceptions and performance

Prior to participation in treatment, students were asked to complete the Professional Science Impact Instrument (Appendix A), Student Interest Inventory (Appendix B), and the Science Concept Quiz (Appendix C). Rationale for instrumentation is provided in Table 3.

The “Fairchild Environmental Challenge”

The “Fairchild Environmental Challenge” is an environmental science competition that solicits participation from primary and secondary public and private schools within the South Florida region. Multiple environmental science challenges are offered through the “Fairchild Environmental Challenge,” and, during the 2016-2017 academic school year, the competition offered two special citizen science challenges that were carried out in partnership with professional science agencies. Of the two citizen science projects, my bioscience students participated in *Growing Beyond Earth (GBE)*, offered through NASA and the Fairchild Garden (See Figure 1). Information on the *GBE* challenge requirements can be found in Appendix D.



Figure 1. *GBE* is an extension of NASA’s Veggie Program, offered conjointly through the Fairchild Gardens. NASA’s Dr. Gioia Massa and Dr. Trent Smith were the lead researchers involved in *GBE* and they are shown in the above image on the right.

Treatment

NASA’s Veggie Program invited students to contribute to the growing body of research on plant atrium systems for deep space through the *GBE* challenge. Students investigated growth conditions for several cultivars of leafy green vegetables in controlled climate plant chambers provided through the Fairchild Challenge and NASA

during a 90-day grow-out trial. Participation in this project began in early September of 2016, and the close of the trial period was at the beginning of December of that same year. Data collection for pretreatment began in early September and posttreatment data collection occurred at the end of February. Pretreatment consisted of the administration of the Professional Science Involvement Impact Instrument (Appendix A), the Student Interest Inventory (Appendix B), and the Science Concept Quiz (Appendix C). Posttreatment included the subsequent administration of the aforementioned evaluation tools.

As a part of treatment, students collected and interpreted plant data weekly and worked on developing key process-based, research skills for scientific investigations. Contact time for the project following set-up of the plant atrium in September was anywhere between 5 to 15 minutes a class period, and included daily observations on plant health, classroom and atrium temperature, relative humidity, and student-made decisions regarding the watering regime (See Figure 2). Biometric data collections needed to be done once weekly, and, ideally, around the same time of day. Because the amount of time for such measurements was more intensive than other data collection (about 45 minutes), I utilized a group of six interns who recorded the necessary data during the last period of the day at the end of each school week. While the project was in progress, instructional content moved on to discuss such topics as applications of project findings for growers in Florida to draw connections with the focus of the bioscience curriculum, research methodologies using peer-reviewed databases, peer-reviewed paper breakdowns, proposal writing, and research presentation skills.

Following the close of the 90-day trial period, students were asked to consider the success of their randomly assigned cultivars, watering regimes, or other growth conditions, based on their observations, in order to provide NASA’s Veggie Program with insight on optimal cultivars and protocols for the International Space Station. Students had the opportunity to explore challenges associated with plant atrium designs, cultivar strains, and protocols for plant upkeep and harvest during the growth trial. Students were provided additional time to process their data and to perform additional research at the trial’s end to be able to construct their own research proposals on content related to the *Growing Beyond Earth* Challenge. Two student proposals were selected from the bioscience class submissions and submitted to the Fairchild Tropical Botanic Gardens “Fairchild Challenge” review committee. Students were asked to complete the proposal individually, though protocol during treatment was highly collaborative. Competition submissions were due by February 22, 2017 to the review committee, but needed to be submitted to me by February 1st. For a more detailed overview of treatment activities, see the logic model presented in Table 2.

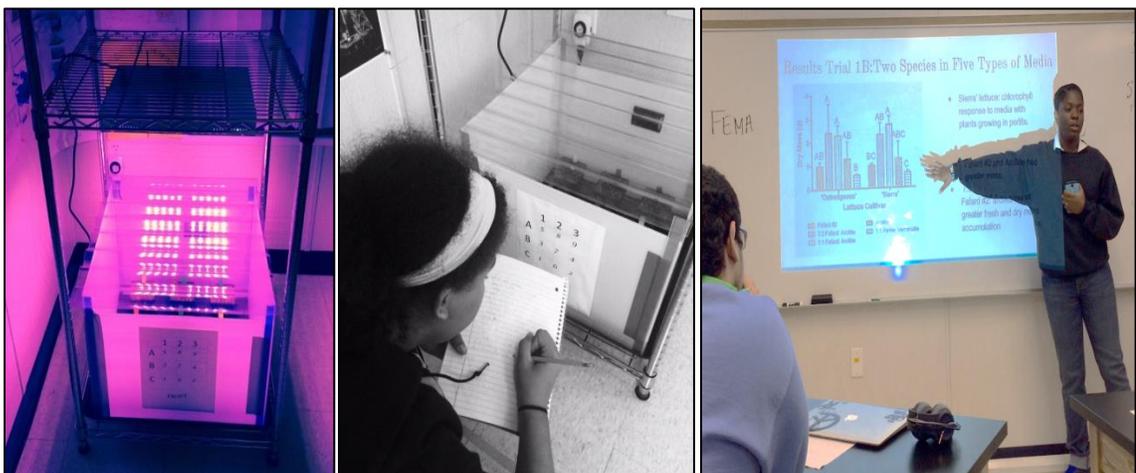


Figure 2. (From left to right) *GBE* plant atrium, student performing daily observations on plant health, and student presenting NASA *GBE* research.

Instrumentation

In order to evaluate the impact of GBE participation on student attitudes, academic performance, and STEM retention, students were asked to respond to three instruments I developed for this action research project in a pretreatment and posttreatment fashion. Instruments developed for this study do not borrow from pre-existing instruments and were named for ease of referencing. They include the following: the Professional Science Impact Instrument (PSII), the Science Concept Quiz (SCQ), and the Student Interest Inventory (SII). Pretreatment responses were collected between late August and early September. Posttreatment responses were recorded in February following the submission of student research proposals and the close of all treatment-related activities.

The PSII (Appendix A) assessed student beliefs and perceptions about their science courses at MAST @ FIU over a series of 11 questions, with some open-ended questions on demographics. Questions one through three assessed how relevant students felt science content is to their daily lives; questions four through six, and nine through 11 investigated the meaning that students derive from science coursework and professional science activities in the classroom; and questions seven and eight assessed student perceptions about their engagement in science courses when professional science activities are involved.

The pretreatment administration of PSII was offered to students as a voluntary hard-copy, take-home exercise. Students across all three periods were handed hard-copies at the end of class over two consecutive days in September (September 12th and 13th,

2016) for pretreatment assessment, whereas online administration methods were utilized for the posttreatment assessment via Survey Monkey. Only students who completed the pretreatment PSII were asked to respond to the posttreatment PSII survey, which was sent as a link via email on February 27, 2017. Each student was then given until March 7, 2017, to complete PSII questions. It is important to note that revisions to the instrument took place following its pretreatment administration. Changes were minimal in that they involved the rearrangement of a few questions and added clarification to terms on paper that were orally defined at the time of administration.

The Student Interest Inventory (Appendix B) consisted of 15 questions that targeted information relating to post-secondary school aspirations, as well as class and learning preferences. The SII was administered at the end of August, prior to there being any mention of involvement in *GBE*, via a paper-based handout. Responses to the SII were used to provide additional insight on student beliefs to incorporate into instructional strategies and to establish a baseline of student goals regarding their desires to remain in STEM programs. Inventories prompted students to respond to open-ended questions regarding general coursework, personal history, and considerations about life beyond high school to provide me with a more holistic view of my students as individuals.

To evaluate the impact of professional science involvement on student comprehension of process-based science skills, the Science Concept Quiz (Appendix C) was administered. Students were asked to identify key elements in experimental studies over four questions, such as the control, independent, and dependent variables. Student-generated artifacts (Appendices F and G) were also used to monitor basic skills

development owed to aspects of the citizen science project before, during, and after project completion. Journal reflections, formal paper assignments, and annotated bibliographies are all examples of student work samples used to evaluate the impact of professional science involvement on academic performance. Field notes were taken to document any notable signs of behaviors that suggested extremes of responses, whether good or bad, to content.

Table 3
Data Triangulation Matrix

<u>Focus Question:</u> How does professional science involvement impact honors bioscience students?			
1. Student attitudes?	Pretreatment/posttreatment: Professional Science Impact Instrument to monitor changes in attitudes owed to treatment	Pretreatment/posttreatment: Student Interest Inventory to allow students to self-identify attitudes/ perceptions toward STEM content	Pretreatment/post-treatment: Teacher field notes
2. Student academic performance?	Pretreatment/posttreatment: Science Concept Quiz to evaluate learning gains owed to treatment	Pretreatment/posttreatment: Student Work Samples to demonstrate concept application	
3. Retention in STEM-programs?	Pretreatment/posttreatment: Student Interest Inventory to allow students to self-identify STEM career options of interest		

Validity and Reliability

In an effort to ensure reliability and validity of treatment methods, careful consideration went into the development of evaluation instruments. The Professional Science Impact Instrument incorporated Likert items that were constructed specifically for use in this action research project, with the intent of evaluating my students’ responses to participation in the *Growing Beyond Earth* project (treatment). Likert items do not borrow from any published instruments, though all items were written with the target audience and treatment methods in mind. The Science Concept Quiz was written to

assess the applied concepts that were being reinforced through participation in treatment. Lastly, the Student Interest Inventory allowed respondents to self-identify career goals to determine the percentage of students planning to remain in STEM fields. Offering students the chance to openly respond to the questions in the SII, I feel, is a truer reflection of their goals. To further supplement these data, qualitative data were recorded by me through field notes. Non-verbal and verbal forms of communication in response to treatment activities were observed. All research methodologies used during this action research project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (See Appendix E).

DATA AND ANALYSES

Prior to being informed of the activities involved in *GBE*, students responded to the pretreatment instruments. Some students were immediately on board with the action research project, some were a little hesitant, while others were preoccupied with their workloads. As a result, I had 60.24% of students respond to the PSII and to the SII; though I had 100% of students complete the SCQ (*N* total, 83). I suspect that students felt obligated to respond to the SCQ because it had the word "quiz" in its name, even though they were made aware of the fact that their participation was optional. At the beginning of the treatment period following a presentation of the treatment plan and introduction to *GBE*, the majority of students (~85%, *N*= 83) expressed feelings of "excitement" and were eager to begin working on a project that could lead to more direct involvement with NASA. Though they were not quite sure about how the project would play out, students

were hopeful that at least one of them would get the chance to present his/her research to Dr. Gioia Massa (NASA), Dr. Trent Smith (NASA), and the Fairchild researchers.

As the treatment period progressed, student interest levels seemed to wane, as many different concepts were being covered through the continuation of the bioscience curriculum, and the demands of the school year were wearing on them. My engineering students, in particular, seemed to grow weary of the daily observation periods and verbalized feelings of disinterest. Even at the close of the 90-day growth trial in December, students only slightly expressed enthusiasm for the project. Following our return from the two week winter break in January of 2017, students displayed a rejuvenated sense of anticipation as we began the proposal writing process. As I collected student proposals in February and selected the top two for *GBE* submission, students who did not make it past my evaluation round were visibly disappointed. Upon announcement of my decision regarding *GBE* submissions, I considered the treatment period complete, and I administered the posttreatment round of evaluation instruments. The discussion that follows is a comparison of the data that were collected in early September of 2016 and the data that were collected in late February/ early March of 2017.

Instrumentation Evaluation

Professional Science Impact Instrument

The Professional Science Impact Instrument (PSII) (Appendix A) was designed to target quantitative data about how student attitudes toward professional science involvement in bioscience changed following treatment. Students were asked to respond to 11 Likert items. Results for pretreatment and posttreatment responses to Likert items

are shown in Table 4. Due to the voluntary nature of this action research project, students were not required to respond to the PSII. Of the entire bioscience population ($N = 83$), 66.27% responded to the paper-based pretreatment, and, of that percentage, only 54.55% (36.14% of $N= 83$) responded to the online posttreatment PSII. Because original responses were collected via paper-based format anonymously, it was not possible to remove all of the individuals who elected not to respond to the posttreatment administration session. Because student email addresses were provided during the first PSII administration round, it was possible to send posttreatment links via email only to those students who participated in the pretreatment administration. The discussion that follows explores the changes in percentage values on Likert items following treatment, though extrapolating conclusions from data should be guarded due to the discrepancy between the values for N between pretreatment and posttreatment.

Items one, four, and seven through nine all asked respondents questions regarding favorable aspects of professional science involvement in the classroom, with an emphasis on the frequency of occurrence of the feeling; items two, five, and ten represented moderate frequency of positive associations with professional science in the classroom; and items three, six, and 11 were negatively stemmed and represented seldom occurrence of the behavior. In general, higher values on items one and two, three, four, and seven through ten would suggest positive attitudes toward professional science involvement in the classroom; whereas, higher scores on items three, five, and 11 would suggest negative sentiments for professional science participation due to the negative stemming of the question. In other words, it was expected that students who identified with “almost

always agreeing” or “strongly agreeing” about feeling positively towards a construct would report “disagreeing” or “strongly disagreeing” when asked if the feeling “almost never” occurs. A noticeable trend in positive feelings toward STEM was supported with data collected during both pretreatment and posttreatment evaluation, though infographics here do not dissociate data down to each individual respondent and reflect aggregate responses, instead.

Values reported for the standard deviations among Likert item responses for pretreatment evaluation showed the greatest amount of variability for items that asked students to consider whether they felt that professional science involvement in the classroom “almost always” or “almost never” met certain expectations. As many of my students have experienced some type of professional science involvement previously, such as guest lectures from FIU research scientists and professors, it is possible that they are more critical about the nature of involvement. Posttreatment PSII values reflected shifts that diminished the deviation amongst responses to Likert items, which suggests that the students who responded to the instrument shared beliefs more closely, though it is possible that this is not an accurate reflection of the entire bioscience population due to the smaller sample size.

Means calculated for Likert items suggest that a majority of respondents had positive feelings about professional science involvement in the classroom prior to participation in the Fairchild Challenge treatment. Though posttreatment evaluation reflected a drop in the average values for negatively associated constructs, I attribute that to some students realizing the amount of work associated with STEM projects and deciding that it is not

quite for them. In my opinion, providing students with opportunities that more closely mimic the real world applications of STEM and the nature of the related workload better prepares them for making decisions about majors and careers post-secondary school.

While the data reported herein do not support this idea outright, anecdotal evidence from conversations with my students suggested that the project did help them to better understand the demand of research scientists.

Table 4.

Professional Science Impact Instrument: Pretreatment (Blue, N=55) and Posttreatment (red, N=30) Responses

Item #	1	2	3	4	5	6	7	8	9	10	11
(f) of response reported in % of respondents											
Strongly Disagree	5.45 +4.55	0 NC	29.09 -2.42	5.45 +1.22	1.82 -1.82	20.00 +16.67	3.64 -0.31	3.64 -0.31	1.82 +1.51	0 NC	20.00 +16.67
Disagree	14.54 -4.54	7.27 +2.73	49.09 +20.91	10.91 +2.42	10.91 +2.42	54.55 -4.55	10.91 +9.09	3.64 +6.36	9.09 +7.58	9.09 +4.24	47.27 +2.73
Neutral	18.18 +5.15	34.54 -18.87	10.91 -10.91	18.18 -11.51	25.45 -8.78	10.91 -7.58	14.55 -7.88	25.45 -18.78	21.82 -5.15	41.82 -18.49	23.64 -16.97
Agree	36.36 +10.31	47.27 +2.73	7.27 -3.94	18.18 +5.15	50.91 -7.58	9.09 +0.91	38.18 -14.85	52.73 -19.40	45.45 -12.12	41.82 -1.82	9.09 -5.76
Strongly Agree	25.45 -15.45	10.91 +12.42	3.64 -3.64	47.27 +2.73	10.91 +15.76	5.45 -5.45	32.73 +18.06	14.55 +32.12	21.82 +8.18	7.27 +16.06	0 +3.33
Values are scored as Likert items											
Standard Deviation	1.17 -0.03	0.77 +0.04	1.01 -0.49	1.25 +0.08	0.89 +0.10	1.05 -0.15	1.1 +0.20	0.89 +0.23	0.91 +0.27	0.76 +0.22	0.87 +0.07
Mean	3.62 -0.25	3.62 -0.02	2.07 -0.14	3.91 +0.06	3.53 +0.30	2.25 -0.38	3.85 +0.05	3.71 +0.39	3.78 -0.08	3.47 +0.26	2.22 -0.35

Note. 5=Strongly Agree, 4=Agree, 3=Indifferent, 2=Disagree, 1=Strongly Agree.

Student Interest Inventory

Of the total bioscience population ($N = 83$), 66.27% responded to the paper-based administration of the pretreatment SII, while only 36.14% responded to the online posttreatment. Again, it was not possible to omit all student data from individuals who did not respond to the posttreatment administration of the SII, due to the anonymous collection format and the inability to determine ownership of all email addresses. Student Interest Inventories were meant to provide students the opportunity to self-identify career

goals at the point of administration. Results of the pretreatment and posttreatment administration of the SII are reflected in Figure 3. STEM careers were considered to include studies in medical science (human and non-human animals), engineering and computer science (including biomedical engineering), biological research (non-human), education, and psychology. Pretreatment evaluation showed that a large portion of students (52.72%, $N=55$) identified STEM careers as future career goals, while roughly a quarter (27.27%, $N=55$) were undecided. This suggests that students not only had positive preconceived notions about professional science involvement, also indicated by the Professional Science Impact Instrument, but that students were actively considering future career options within STEM fields prior to treatment.

Following participation in *GBE* treatment, a larger percentage of students (59.99%, $N=30$) reported that they were interested in pursuing STEM careers, while a smaller percentage of students were undecided (13.33%, $N=30$). This suggests that participation in *GBE* fostered interest in STEM, and, though drops were seen in some STEM career categories, I find that the decrease in the percentage of undecided students to be really encouraging. It is difficult to determine, however, the overall impact of treatment in this study due to the inability to survey all original respondents posttreatment and to the inability to dissociate impact of non-treatment instruction. Though data reflect a relative increase in the overall percentage of students choosing to pursue a career in STEM, the total number of respondents for the posttreatment SII was not equivalent to the pretreatment, so caution is warranted in extrapolating meaning from these results.

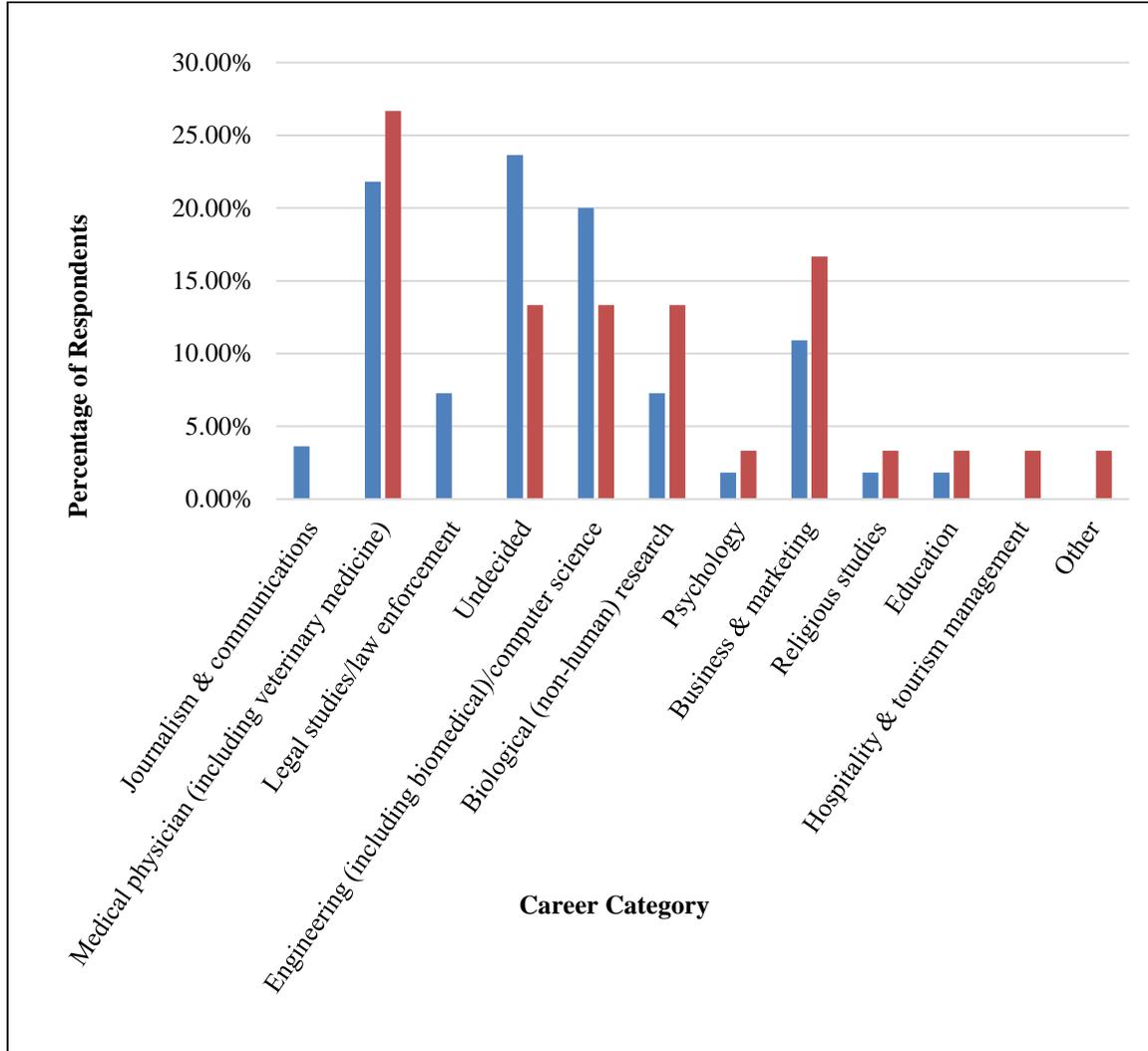


Figure 3 . Student-identified career categories from the SII, pretreatment in blue ($N=55$) and posttreatment in red ($N=30$).

Science Concept Quiz

The Science Concept Quiz assessed student knowledge of experimental design and relied on science processes derived from the Fairchild Challenge, rather than science content specifically. The average score from the entire population of bioscience students ($N=83$) on the pretreatment administration of the Science Concept Quiz was 32.41 points out of a 50 point scale, which equates to 64.82%. The average score on the quiz

posttreatment was 39.82, or 79.64%. This increase in student performance suggests that students were able to better comprehend skills-based science processes after participating in the *GBE* treatment.

Following an analysis of scores ($N=83$) on the pretreatment and posttreatment assessments using a Wilcoxon Signed-Rank statistical test, at a critical value of $p \leq 0.01$, results were found to be statistically significant (The Z-value is -5.6925. The p-value is 0. The result is significant at $p \leq 0.01$). This statistical significance suggests that posttreatment scores were positively impacted by *GBE* treatment. However, it is unclear whether students performed better on the administration of the Science Concept Quiz posttreatment due to instructional strategies alone. Because SCQ questions were the same during both administration periods, it is possible that students were able to better perform because of quiz content reviews and/or other confounding variables. In attempt to control the influence of repeat questions, SCQ pretreatment and posttreatment administration was split by almost 4 months.

Further disaggregating the data by class period (See Figure 4) revealed that averages for periods 1, 3, and 4 on the pretreatment SCQ assessment were 71.48% ($N=22$), 63.68% ($N=26$), and 61.48% ($N=35$) respectively. Posttreatment averages for each period were 84.32% ($N=22$), 81.92% ($N=26$), and 75.00% ($N=35$). Wilcoxon-Signed Rank analysis was subsequently performed for each of the bioscience class periods. Period 1 analysis returned a W-value of 0. Due to the nature of the Wilcoxon-Signed Rank test, data points that resulted in a 0 absolute difference were discarded and reduced the value for N that was used in calculation. For period 1, the critical value

of W for $N = 13$ at $p \leq 0.01$ is 12. Therefore, the result was significant at $p \leq 0.01$. For period 3, posttreatment results returned a Z -value of -3.2999 and a p -value of 0.00048 at $p \leq 0.01$. Lastly, analysis of period 4 SCQ showed that posttreatment scores were also significantly different, with a Z -value of -3.253 and a p -value of 0.00058 ($p \leq 0.01$).

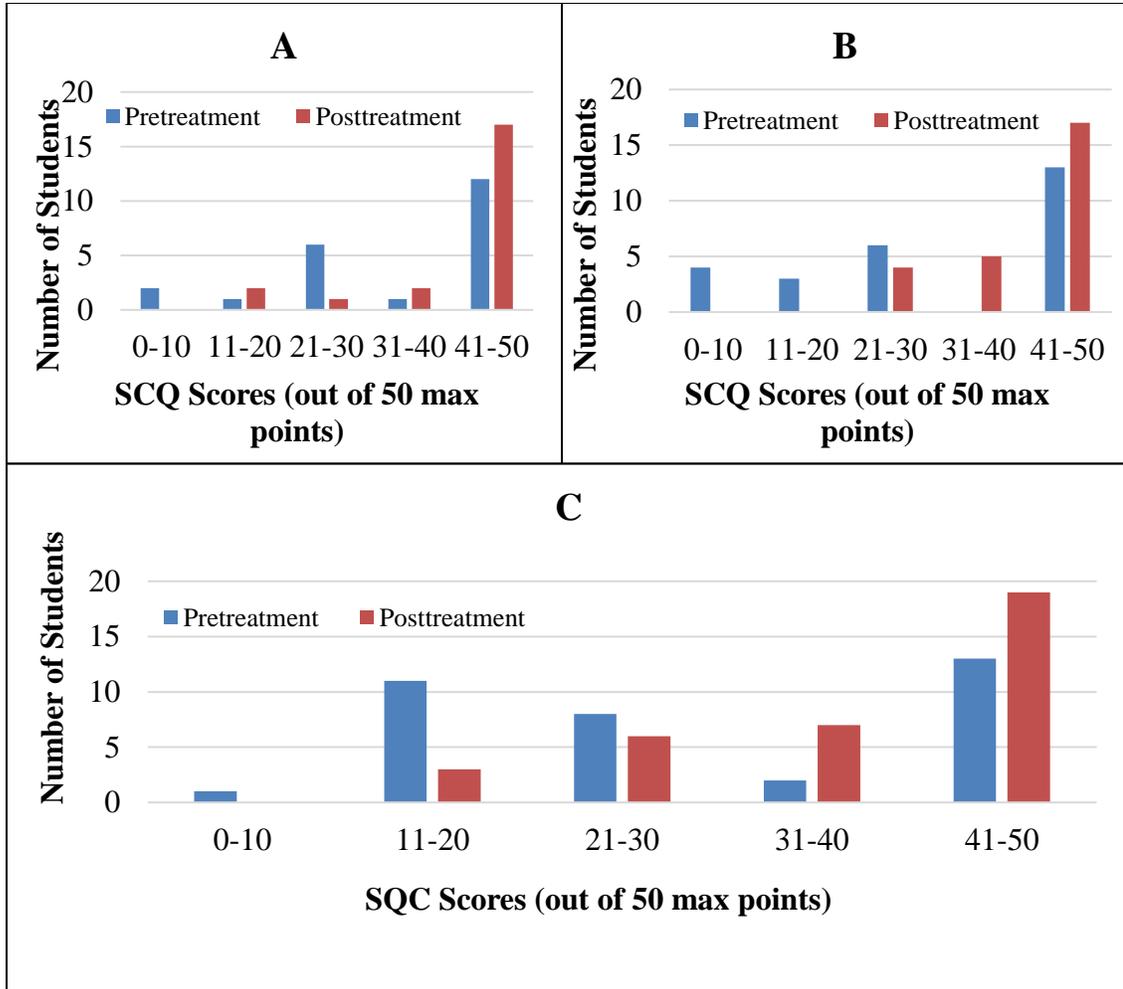


Figure 4. Figures A, B, and C represent student scores on the Science Concept Quiz before and after participation in treatment for periods 1 ($N=22$), 3 ($N=26$), and 4 ($N=35$), respectively.

INTERPRETATION AND CONCLUSION

The purpose of this research was to explore the impact of professional science involvement in the MAST@FIU honors bioscience classroom. Students participated in the *GBE* citizen science project offered by the Fairchild Tropical Botanic Gardens in partnership with NASA. To evaluate the impact of participation in *Growing Beyond Earth*, students were asked to respond to a series of questions across three instruments: the Professional Science Impact Instrument (PSII), the Student Interest Inventory (SII), and the Science Concept Quiz (SCQ).

Pretreatment results of the PSII demonstrated that student attitudes were generally positive about participation of professional science in the classroom, but that the frequency of their sentiment was felt only “sometimes.” Following treatment, results of the PSII showed no significant differences in student attitudes, though minor drops were seen in the percentage of responses to negatively associated items. Even though not all of the shifts observed on the PSII reflected positive sentiments towards professional science and STEM, I felt that this project helped students better understand the demands for STEM professionals, and, as a result, they can make more informed decisions about their work and studies post-secondary school.

The percentage of students identifying STEM careers or studies as future options through the Student Interest Inventory grew from 52.72% ($N=55$) pretreatment to 59.99% ($N=30$) posttreatment. The percentage of students that responded with “undecided” decreased following the close of the treatment period, which I found to be an encouraging response to treatment participation. It is important to again note, however, that the

number of students responding to the posttreatment administration of the SII was only about 50% of the original number of respondents, so the increase in percentage points might be an artificial representation of the actual amount of students currently wishing to pursue STEM careers or studies.

Score results of the posttreatment administration versus the pretreatment administration of the Science Concept Quiz were found to be statistically significant using a Wilcoxon-Signed Rank test. The SCQ returned 100% of responses from the original population of bioscience students ($N=83$) and it is therefore the strongest evidence for positive impact following *GBE* treatment. Results of this instrument serve as the most compelling evidence for the positive impact that professional science involvement has on MAST@FIU students. It is not possible to state however, whether this difference was due to treatment-based instructional strategies alone, as there were multiple confounding factors coming from non-treatment-based instruction.

Overall, I believe that the effort spent to incorporate real world, research-based problem solving in the classroom had a positive impact on my students' attitudes, academic performance, and future career paths, even if the exact amount evades quantification. In personal conversations with my students, their feedback regarding the opportunity was very positive and, following submission of the two top research proposals from MAST students and evaluation of submitted proposals by Fairchild researchers, one student was even invited to discuss her research with the NASA lead scientists on the *Growing Beyond Earth* project, Dr. Gioia Massa and Dr. Trent Smith

(See Figure 5). In the future, I intend to continue using surveys to assess student perceptions of my instructional practices.



Figure 5. MAST @ FIU 11th grade student presenting her research, *Supplementing Watering Regimes with Urine*, to Dr. Trent Smith of NASA. The image on the right shows the same student standing beside her father, who was beaming with joy.

VALUE

The process of researching the impact of my instructional strategies through this action research project has made me more cognizant of how to identify and satisfy the diverse needs of my students. I have learned to use multiple evaluation instruments to interpret student behaviors and attitudes in order to inform the development of my own best practices for my classroom. While I was not able to definitively find support for the argument that professional science involvement positively influences student attitudes and STEM retention, I was able to show that *GBE* involvement had statistically significant, positive effects on academic performance and thereby justify the rationale for participating in this type of a citizen science project. I am looking forward to having my students once again compete in the upcoming 2017 – 2018 *GBE* Fairchild Environmental

Challenge and I am excited to try and increase the number of my survey responses next year to improve the accuracy of my findings in an effort to continue developing best classroom practices. I intend to keep Likert-styled surveys in my instructional toolkit and to improve upon my abilities to construct Likert items by devoting future time to research and reading. Moreover, because the Fairchild Challenge included a social media component, I had to familiarize myself with a new kind of social media platform, and I expanded my skillset in the process of educating my own students. Ultimately, I found the MSSE capstone research process to be extremely rewarding and critical in fostering my professional educator skillset.

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APPENDICES

APPENDIX A
PROFESSIONAL SCIENCE IMPACT INSTRUMENT

Professional Science Impact Instrument (PSII)

Please complete the below survey to the best of your ability and in its entirety. Participation in this research is voluntary and your decision regarding whether or not to participate will not affect your grade or class standing in any way.

1. I *almost always* feel as though the content being taught in my science courses is applicable to my daily life.
Strongly Disagree Disagree Neutral Agree Strongly Agree
2. I *sometimes* feel as though the content being taught in my science courses is applicable to my daily life.
Strongly Disagree Disagree Neutral Agree Strongly Agree
3. I *almost never* feel as though the content being taught in my science courses is applicable to my daily life.
Strongly Disagree Disagree Neutral Agree Strongly Agree
4. I *almost always* feel as though science courses would be more meaningful if I had the opportunity to participate in real/professional science projects/experiments.
Strongly Disagree Disagree Neutral Agree Strongly Agree
5. I *sometimes* feel as though science courses would be more meaningful if I had the opportunity to participate in real/professional science projects/experiments.
Strongly Disagree Disagree Neutral Agree Strongly Agree
6. I *almost never* feel as though science courses would be more meaningful if I had the opportunity to participate in real/professional science projects/experiments.
Strongly Disagree Disagree Neutral Agree Strongly Agree
7. I would take projects more seriously if I knew that they were a part of professional science/research.
Strongly Disagree Disagree Neutral Agree Strongly Agree
8. Opportunities to participate in citizen science projects would make more learning more exciting to me.
Strongly Disagree Disagree Neutral Agree Strongly Agree
9. I *almost always* feel as though participation of post-secondary institutions, such as colleges and universities, in my classes would make learning more meaningful to me.
Strongly Disagree Disagree Neutral Agree Strongly Agree
10. I *sometimes* feel as though participation of post-secondary institutions, such as colleges and universities, in my classes would make learning more meaningful to me.
Strongly Disagree Disagree Neutral Agree Strongly Agree
11. I *almost never* feel as though participation of post-secondary institution, such as colleges and universities, in my classes would make learning more meaningful to me.
Strongly Disagree Disagree Neutral Agree Strongly Agree

Demographic Information:

Name: _____ Gender: _____ Age: _____
 Grade: _____
 Ethnicity: _____
 Current Job Aspirations: _____
 Please list your previous science coursework in the remaining space and write the grade you took those courses in.

APPENDIX B
STUDENT INTEREST INVENTORY

)

Please complete the below survey to the best of your ability and in its entirety. Participation in this research is voluntary and your decision regarding whether or not to participate will not affect your grade or class standing in any way.

1. Where are you from and is English your first language?
2. How many people are in your immediate family?
3. What's your favorite class in school? Why is it your favorite?
4. What's your least favorite class in school? Why is it your least favorite?
5. Which class is the most challenging to you (it does not have to be the least favorite or favorite class)? Is that challenge positive or negative and what about the class is so challenging?
6. How do you learn best (audio, visual, hands-on, etc.)?
7. What can a teacher do to captivate your interests? Please give me an example.
8. What size group do you prefer to work in when it comes to projects (you can say independently)? Why?
9. What do you want to do after high school?
10. What are a few of your hobbies?
11. How much would you say you use technology if you had to quantify the amount of time spent within one week?
12. Do you have any responsibilities beyond the classroom (*i.e.* work, babysitting siblings, extracurricular clubs like..., church/religious responsibilities, etc.)?
13. Do you have a special talent or an interest that you know a lot about? If so, what is it?
14. Tell me about a past accomplishment that made you feel proud of yourself.
15. Is there anything else you want me to know about you?

APPENDIX C
SCIENCE CONCEPT QUIZ

Science Concept Quiz (SCQ)

Instructions: You have 10 minutes to read and identify the requested information from the study described below. **Please complete the below to the best of your ability and in its entirety. Participation in this research is voluntary and your decision regarding whether or not to participate will not affect your grade or class standing in any way.**

Dr. Derisca and his team of researchers are investigating a new chemical compound known as “Chemical X.” “Chemical X” is designed to enhance human physical and mental performance to near limitless boundaries. In order to investigate the causal relationship between the chemical compound and its influence on physical and mental performance of participants, Dr. Derisca *et al.* (2016) design their study as follows:

- 3 participants receive “Chemical X” for a period of 3 weeks; all females
- 3 participants receive a “Pseudo-Chemical X” for a period of 3 weeks; 2 females and one male

Following the trial period, participants were evaluated through physical and mental aptitude tests (range 0-100) and results were analyzed to compare **male v female performance on each exam, and participants who did v who did not receive “Chemical X” performance on each exam.**

Identify the following:

- 1) **independent,**
- 2) **dependent,**
- 3) **control,** and
- 4) **one of the four kinds of statistical variables,** not including quantitative or qualitative.
 - For each variable you must provide the corresponding component of the study.

Bonus: What do you think happened to the participants who received “Chemical X” OR what could Dr. Derisca and his team do to enhance their study?

APPENDIX D

FAIRCHILD CHALLENGE *GBE* REQUIREMENT



Challenge 5 - Growing Beyond Earth

For individuals or groups; maximum points: 450 (200 per proposal; 50 bonus points)

YOUR CHALLENGE: For NASA, growing plants in space is critical for future space exploration. [NASA's VeggieProgram](#) researchers and Fairchild's team of student citizen scientists have identified several plant species that meet all growing and nutritional requirements for growth in space. Using these target species, test growing conditions in your specially designed growth chamber that mimics the conditions on the International Space Station. Throughout the school year, you will observe plant growth, share your observations on Twitter, and enter your data into an online database. Evaluate your findings and create an experiment that addresses a question that arose from your observations. Write your scientific question, a possible hypothesis, and propose a methodology for answering that question.

ENTRY SUBMISSION: Wednesday, Feb. 22, 2017 by 5:00 p.m.

Electronically submit the following materials:

- (a) [Challenge 5 Entry Form](#)
- (b) Maximum **two research proposals per school**
- (c) Data sheets (*available after PARTICIPATION REQUIREMENT is fulfilled*)
- (d) Tweets* with school name, @FairchdChallnge, and #GrowingBeyondEarth

PARTICIPATION REQUIREMENT: Schools are **required** to submit the [Memorandum of Understanding](#) by **Friday, September 2, 2016** if they plan to participate in this challenge.

TEACHER PREREQUISITE: Teachers interested in participating in this challenge are **required** to attend an intensive professional development training at Fairchild before receiving supplies (see Teacher Workshop information below).*

ENTRY REQUIREMENTS:
Weekly updated data entry on provided data
20 – 30 student-created, scientifically relevant tweets* with school name, @GrowBeyondEarth
Research proposal must be approximately 500 words, typed, double-spaced, using 12-point font submitted electronically in Word Format
Students' name, grade, and school name on entry
Reference page with at least 2 references supporting proposed experiment
On time entry submission (late entries may not receive points)

***Tweets must include all required information in order to receive points.**

ADDITIONAL INFORMATION:

- Paper must be written in student's own words. Plagiarized papers will be penalized. See [Program Policies](#).
- **Selected top entries** will be invited to present their project to judges for final awards placement at Fairchild's Student Showcase on Saturday, March 4th. This event is open to the public.

DATA SHEETS: Schools that have completed the [Memorandum of Understanding](#) will be granted access to their data sheet at the bottom of the page. If you do not see the link and have submitted the form, please contact us at challenge9-12@fairchildgarden.org

BONUS POINTS: Schools will receive a maximum of 50 bonus points for submitting their complete observation lab notebook(s) showing the experiment's data, observations, and notes throughout the trial period.

EVALUATION CRITERIA: For more information on how your submission will be evaluated, visit [Challenge 5 Evaluation Sheet](#).

TEACHER WORKSHOP: Teachers participating in this challenge are required to attend GROWING BEYOND EARTH on SATURDAY, SEPTEMBER 10. For more information visit [Teacher Workshops](#). Please [register for this workshop](#).

STATE ACADEMIC STANDARDS: This challenge meets standards for Gifted, Health Education, Mathematics, Reading/Language Arts, Science and Social Studies, and Theatre. Visit [Challenge 5 Benchmarks](#) for more details.

APPENDIX E
IRB APPROVAL



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

960 Technology Blvd, Room 127
 c/o Microbiology & Immunology
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Administrator:
 Cheryl Johnson
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 cherylj@montana.edu

MEMORANDUM

TO: Bridget Gunn and Walt Woolbaugh
FROM: Mark Quinn *Mark Quinn et al*
DATE: October 27, 2016
SUBJECT: "Investigating the Impact of Involvement in Citizen/Professional Science Project-Based Learning (PBL) Activities on Students at the Marine Academy of Science & Technology at Florida International University (MAST@FIU)" [BG102716-EX]

The above research, described in your submission of October 27, 2016, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

APPENDIX F
STUDENT WORK SAMPLE 1

Student Work Sample 1: Research proposal submission to the Fairchild Challenge

I. Introduction

Voyages to space are costly and require sufficient resources to properly care for astronauts. Resources should be used efficiently to ensure long lasting supply because resource availability in space is limited. Since the International Space Station (ISS) does not have fuel cells, water is not produced and would have to be supplied from the ground. To remove contaminants from spent water, a filtration system is used. However, some of the water is lost in the process, which reduces the amount of water supply that may be used for consumption. The veggie unit used in the “Growing Beyond Earth” project is an exploratory measure in space crop cultivation. Because one of the basic needs for plants in this unit is water, which is finite on the ISS, a way to more efficiently manage spent water is to use human urine as a supplement. The main organ in the excretory system, the kidney, filters extra water and wastes from the blood to produce urine. Urine can be used as a supplement to water for nutrient uptake like a fertilizer in plants since it contains rich macronutrients such as nitrogen (N), potassium (K), and phosphorus (P). According to a study by Rajani *et al.* (2015), human urine was successfully used as a fertilizer on *Solanum lycopersicum* and *Capsicum sp.* The tomatoes and peppers used in the study had an increase in stem height, number of leaves, and amount of N, P, K, concentrations. Rajani *et al.* (2015) also reported that “the urine grown crops also had higher protein and lower fat contents showing prospects for the promotion of health when consumed.” Bosrotsi *et al.* (2015) also used urine as a substitute for fertilizer in vegetables and “trials confirmed the advantage of crop response to urine in the yields of vegetables used.”

II. Purpose/Hypothesis

Is it possible to use human urine as a fertilizer on plants in an effort to restore lost macronutrients, such as potassium, nitrogen, and phosphorus so as to increase crop yield and nutritional content on the ISS?

III. Proposed Methods

A Urine Diversion Dry Toilet systems (UDDT), a type of dry toilet, can be used to collect urine without flushing water. The UDDT has a divider so the urine can be separated from the feces which can have the urine be used directly as a fertilizer for the plants. Since astronauts use a space toilet to recover potable water, a UDDT can replace the space toilet and no water will be lost in the process which will help in managing the amount of limited water there is. It is possible that additional modifications will need to be engineered to account for lack of gravity. Reclaimed urine would then be added in varying quantities as supplements to the watering regime. Quantities of urine would need to be set based off of the potential for microbial development and other human health concerns.

IV. Impact/Benefit

The use of urine as a fertilizer to restore macronutrients lost in plants will have a positive impact on saving the amount of water and nutrients lost in the filtration system to

produce water to provide to the plants. Not only that, since urine contains rich plant nutrients, urine supplements will enhance crop yield and quality, further benefiting the astronauts.

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APPENDIX G
STUDENT WORK SAMPLE 2

Student Work Sample 2: Research proposal submission to the Fairchild Challenge

Introduction: Growing Beyond Earth has major implications for future space exploration and possibly even colonization. Massa *et al.* (2013, 2015) have repeatedly proven that it is possible to grow plants in microgravity aboard the International Space Station. This feat has additional benefits to the crew members besides nourishment, mental health benefits, and aesthetic value. By growing plants tailored to the individual genetic needs of the crew members, we could improve their health. “Research indicates that your blood type is a key genetic factor that influences many areas of health and well-being,” (Blood Type and Your Health, 2015). By acquiring DNA samples from the crew members, scientists can sequence their DNA and make definitive conclusions personalized to each crew member on what cofactors and coenzymes each of their body needs to intake more of or less of. “The facts are clear-cut: In the 6617 individuals who reported their results from following the Blood Type Diet for a period of one month or more, three out of four (71-78%) had significant improvement in a variety of health conditions. Weight loss was the effect most often observed but a number of reports detailed improvements in digestive function, resistance to stress, overall energy and mental clarity,” (Blood Type and Your Health, 2015). “Many of the nutrigenomic profiles available today test for polymorphisms (the SNPs, or 'snips') in certain genes that have been linked to disturbances in body function and which may be amenable to diet and lifestyle changes,” (The Genotype Diet 2010). Once receiving the results, we would then determine which plants would best suit each crew member to grow aboard the International Space Station.

Proposed Question: In order to address the crew member’s individual genotypic needs, we are proposing sequencing their DNA to determine their personal food intake needs. Based on that information, scientists would need to find plants that are high in those specific nutrients and suitable for cultivation aboard the ISS. “Knowing your blood type is an important tool for understanding how your body reacts to food, your susceptibility to disease, your natural reaction to stress, and so much more. A single drop of blood contains a biochemical makeup as unique to you as your fingerprint,” (Blood Type and Your Health 2015). An example according to Be Well Buzz, Swiss Chard has been found to be extremely beneficial to people with blood type A (2015). Plants that fit all criteria would be sent to grow board the International Space Station.

Methods: We have decided to modify the existing protocol. Beginning with a DNA test, which would then be followed by a fitness test, to determine genotypic needs and physical health. Subsequently, we would test proposed crop growth and nutrient levels. To determine the results on the crew’s health we suggest conducting a secondary DNA test and fitness test, which would determine the effects of the individualized, modified diets. These fitness tests and diets will be put to the test before boarding the International Space Station and whilst aboard it.

Broader Impacts: The benefits to personalizing diets based on the genotypic needs of the International Space Station crew members would improve their health for the duration of the long journey in outer space. By enhancing their health, they would be able to reduce their stress, improve their mental health, as well as give their immune system a boost. Bone density is yet another issue faced by many aging adults as well as astronauts

aboard the ISS. By eating this perfect diet, people may be able to maintain or perhaps even improve their bone density. “In addition to sleep and physical activity, a balanced diet is one of the key elements of health and well-being. Healthy eating not only makes you feel good but also has a variety of physical health benefits. Since food fuels bodily processes, it makes sense that good food encourages optimal overall function” (How Does Healthy Eating Affect Your Body 2015).

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