

VIRGINIA AIR & SPACE CENTER

NASA LANGLEY VISITOR CENTER



STEM 360: Multi-Setting, Multi-Platform STEM Education Engagement Program & Research Study



LETTER FROM THE DIRECTOR

In late 2014, a process of transformation commenced to ensure that the Virginia Air & Space Center would not be just a nice place, but an essential place, not just be a provider of STEM programs, but a leader and innovator of STEM education. This is the fundamental strategy that will drive the Virginia Air & Space Center to a new place, hence ensuring not only its relevancy, but sustainability. The STEM 360 research platform is an integral element driving our leadership in STEM education and research. It addresses essential needs of our community and provides a basis for actionable methods to achieve success in fostering STEM education. We are proud of the successes this research project has achieved and we look forward to the next phases that will share and build on what we have learned.

The Virginia Air & Space Center, NASA Langley's Visitor Center, is a 501(c)(3) private non-profit organization that has been educating the community for over 25 years. In an age of accelerating change, success depends on consistently delivering on the promise of excellence. That consistency and reliability rests on the insights and decisions made by paid and volunteer professionals, its governance structure, and the underlying support of its stakeholders. This study is emblematic of an institution that accepts the need to be nimble and adaptive in order to better serve both families and formal educational institutions.

As one reviews and contemplates the results of this unique multi-modal learning program and research study, one should keep in mind that 30 years ago, the United States was third in the world in science education. It has now retreated to 38th, having its third place position supplanted by the Republic of Vietnam.

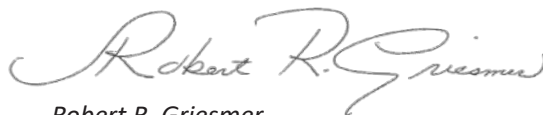
John Dewey, an American 19th century philosopher, who many consider the father of American education, believed strongly that an educated, critical thinking population was essential to preserving democracy. In this global economy, with competing national interests and government systems, Mr. Dewey seems more relevant than ever. Our nation and our children's future are at risk if we do not, once again, capture and hold the high ground in Science, Technology, Engineering and Math. We believe what is described in the following pages is one such strategy to achieve this objective. When we marshal resources intelligently, we can set our community and our Nation on a trajectory to meet the challenges of the 21st century.

I am grateful to our staff, mentors, board, and other volunteers for their hard work and dedication to this endeavor. Danielle Price, the Virginia Air & Space Center's Director of Education & Exhibits, embraced the challenge and drove the project forward.

Dr. John Falk, Executive Director of the Institute of Learning Innovation and Sea Grant Professor Emeritus of Free-Choice Learning at Oregon State University, is an outstanding social scientist whose reputation in the field of free-choice learning is unparalleled. His writing and research in this field has earned him the international reputation that made him the logical choice to participate in and guide this important research project.

I am very appreciative of the talent and dedication of our three school division partners. All three superintendents, Dr. Jeffery Smith, Dr. Deran Whitney, and Dr. George Parker III of Hampton, Suffolk, and Newport News School Divisions, respectively, made this possible. The leads from each division, Ms. Venicia Ferrell, Ms. Shalise Taylor, and Ms. Tami Byron, again respectively from all three divisions, did the heavy lifting of the school divisions. Our non-profit sister organizations provided a strong foundation for making the connections between STEM content and career opportunities. We cannot begin to say thank you to all the individual classroom teachers and parents who enthusiastically supported and guided the participating students.

Lastly, we are grateful to the Virginia Legislature and Department of Education who, through the support of Senator Norment, made this research possible. Delegate Jones also supported the originating legislation and we can now include the Office of the Governor in this truly nonpartisan endeavor. But beyond the statistical positive outcomes of the research, there are the faces of the children who participated. Throughout this report, we have included a few photos because their faces transcend the data, and in the final analysis, that is what it is all about.



Robert R. Griesmer
Executive Director/CEO
Virginia Air & Space Center

OVERVIEW

The STEM 360 Project was conceived as a way to put into practice, as well as holistically assess, years of research findings showing that STEM learning derives not from a single source (schools or visits to science centers), but rather from multiple sources (school, out-of-school free-choice experiences, parental support, and mentoring-type support from other key adults). The STEM 360 Project was designed as a multi-modal, ecosystem approach to enhancing STEM learning.

The study represented a joint effort by the Virginia Air & Space Center (VASC) and the Institute for Learning Innovation, in collaboration with three Hampton Roads area school divisions (Hampton, Newport News and Suffolk), along with a cadre of other free-choice learning organizations (iFLY Virginia Beach, East Coast Polytechnic Institute (ECPI), Norfolk Botanical Garden, Virginia Zoo and Virginia Seafood Agricultural Research and Extension Center- Virginia Tech).

THE STEM 360 PROJECT
WAS DESIGNED AS
A MULTI-MODAL,
ECOSYSTEM APPROACH
TO ENHANCING STEM
LEARNING.



The STEM 360 Project explored whether three different levels of STEM learning enrichment could positively and significantly improve four key STEM learning outcomes:

- 1. STEM Career Awareness**
- 2. STEM Academic Achievement**
- 3. STEM Engagement**
- 4. Attitudes towards STEM**

Four strategies were used to enhance the existing STEM learning environment: In-School Educational Outreaches, Field Experiences to VASC and other local informal STEM institutions, Family and Out-of-School Time Engagement through STEM Ambassadorship, and STEM Coach Engagement and Support.

These educational interventions were scheduled and delivered throughout the school year and were aligned with both the academic calendar and targeted science learning outcomes. An equal number of schools from each of the three participating divisions were assigned to one of **three levels of intervention**:

Level 1 provided the maximum amount of engagement with each of the four interventions.

Level 2 provided a moderate level of engagement.

Level 3 provided minimal or “typical” level of STEM engagement and was considered a control group.

KEY FINDINGS

Over 1,800 students participated in some part of the project, with 1,594 students included in the full two years of research. After two years, all students who participated in the STEM 360 Project demonstrated some measure of benefit, but overall it was students in the Level 1 treatment group – the group with the greatest quantity and quality of STEM 360 Project interventions – who showed the greatest benefits.

“AS WE SEEK TO ENHANCE
INTEREST AND SKILLS IN SCIENCE,
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- DR. JOHN FALK



Level 1 students showed significant growth in all four outcome areas, as well as demonstrated significantly greater growth than did students in either Levels 2 or 3. Specifically, Level 1 students significantly improved their:

- Awareness of STEM careers and interest in pursuing STEM careers.
- Science Academic Achievement as measured by the Commonwealth of Virginia standardized test scores.
- STEM Engagement through participation in group visits to free-choice science learning venues.
- STEM Attitudes and Interests in a range of specific STEM topic areas.

The results provide strong evidence that when key “levers” of educational influence are activated – Enhanced In-Classroom Experiences, Increased Out-of-School Free-Choice Learning Experiences, On-Going Support from Adult Mentors, and Heightened Family Participation and Engagement – students’ STEM career awareness, achievement, engagement, and attitudes can be significantly enhanced.



LOOKING FORWARD

The STEM 360 Project was funded through the Legislature of the Commonwealth of Virginia. Beginning in the 2018/2019 school year, the Virginia Air & Space Center and the Institute for Learning Innovation received an additional two years of funding to work once again with our three school division partners (Hampton, Newport News and Suffolk) and, along with our collaborating free-choice learning organizations, to implement a second round of programming and assessment. This second phase will help determine if the findings from this initial phase of the STEM 360 Project can be replicated and validated with a new cohort of students.

FOR MORE DETAILS VISIT:
www.vasc.org/stem360

“WE BELIEVE THAT NEW LEADERSHIP OPPORTUNITIES EXIST FOR SCIENCE CENTERS WHO ARE ABLE TO SUCCESSFULLY BUNDLE THE COMPONENTS CONSIDERED IN THIS RESEARCH. WE ARE ACHIEVING A MORE PROFOUND RELATIONSHIP WITH SCHOOL DIVISIONS AND OUR SISTER INSTITUTIONS DUE TO THE PARTNERSHIPS DEVELOPED AND THE OUTCOMES BEING ACHIEVED.”

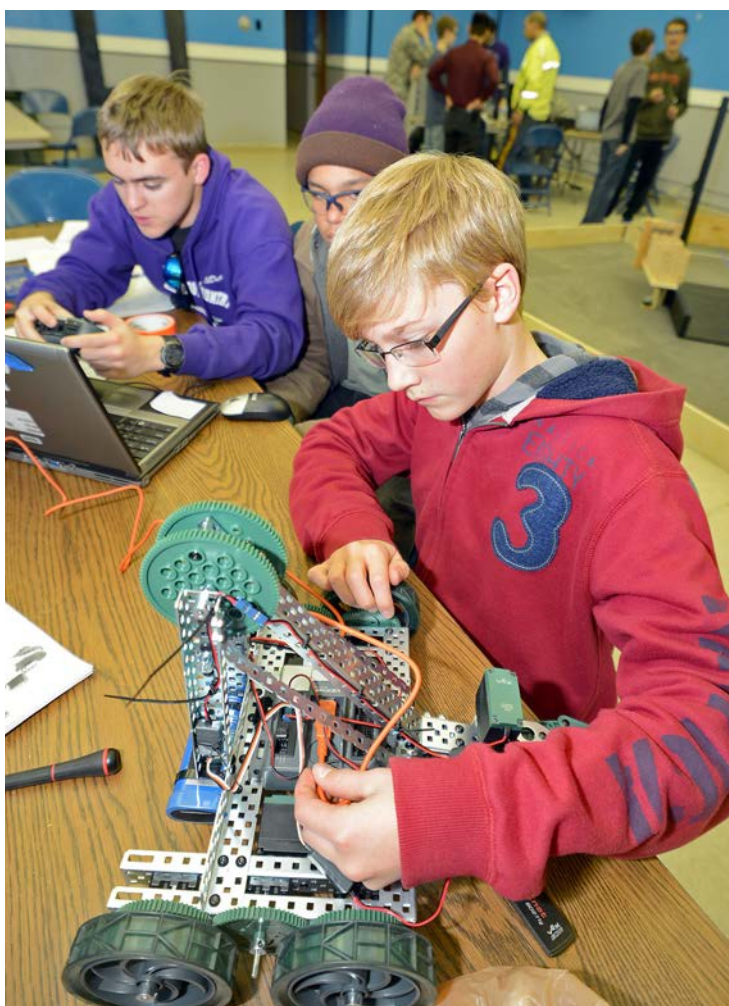
- ROBERT GRIESMER






“STEM Coaches don’t expect that every student will go into a STEM career. We want to foster their curiosity for learning and help them understand that science is needed by everyone to better understand the world in which we live.”

Dr. Michael Kastello, Ph.D.
VASC STEM Coach





STEM 360: Multi-Setting, Multi-Platform STEM Education Engagement Program & Research Study

STEM 360 Phase 1 Report February 2019

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Introduction

Supporting lifelong understanding and participation in STEM needs to be a critical goal of public education. Daily life is increasingly dominated by science and technology and, as a result, the need to continually learn and respond to STEM-related issues is higher than at any time in our history. However, worldwide there is growing evidence that positive attitudes towards STEM learning significantly decline among children after the age of 11 or 12 years (Lacey & Wright, 2009; Maltese & Tai, 2011; Osborne, Simon, & Collins, 2003). These declining numbers, along with a limited awareness of the breadth of STEM careers (e.g., Australian DEPS, 2013; Mokter & Robinson, 2012) result in both fewer STEM professionals and underdeveloped STEM literacy among the public (PCAST, 2010; CoSTEM, 2018). Historically, virtually all resources and energy invested in STEM education have been focused on the schools, however, the lack of significant progress made by these exclusively school-focused reforms suggests that these solutions are not in and of themselves sufficient to solve the problem.

Recent research suggests that STEM literacy and engagement only partially derive from what happens in the classroom (Falk & Dierking, 2010; Falk & Needham, 2013; NRC, 2015). Involving children in STEM learning experiences beyond the classroom— after school, on weekends, and over the summer— significantly increases student career awareness, academic achievement, engagement and attitudes in not only STEM but across all subjects (Alexander, Entwisle & Olson, 2007; CoSTEM 2018; Falk, et al., 2016a; Falk, et al., 2018; Falk & Needham, 2013; NRC, 2009; 2015). In addition, connecting children with interested and engaged adults as coaches or mentors also significantly increases student career awareness, academic achievement, engagement and attitudes (Bright & Hensley, 2010; Gay, 1995; Knight, 2009; Sweeney, 2011). Finally, probably the single most important factor influencing student academic achievement and attitudes is family support (Bogenschneider, Gross & Johnson, 2004; Henderson & Berla, 1994; Henderson & Map, 2002). For example, research suggests that when parents provide materials and resources that support and extend youth STEM interests (regardless of whether the parents themselves share those interests), those youth demonstrate increased positive attitudes and sustained engagement with STEM topics and activities (Barron et. al, 2009).

As the proportion of STEM learning opportunities in free-choice, informal, and self-directed learning contexts continues to grow, communities are beginning to explore how they can better integrate in-school and out-of-school STEM learning experiences to optimize their impact on the publics they serve. This focus on integration of lifelong and lifewide learning opportunities is often described as an ecosystem approach (cf., Falk, et al, 2015; NRC, 2015; Traphagen & Traill, 2014). Although there is increasing recognition of the importance of creating STEM learning experiences that support diverse student participation (e.g., CoSTEM, 2018; Falk & Dierking, 2010; PCAST, 2010; NRC, 2009; 2015), little evidence exists for how a targeted set of approaches— classroom experiences, free-choice learning experiences, adult mentors and family engagement— actually work collectively and for whom. STEM 360 is designed to begin to address this need and better understand how to support students' awareness of the value of STEM in their current and future lives.

The STEM 360 Project

The Virginia Air & Space Center (VASC) in collaboration with the Institute for Learning Innovation (The Institute) and three Hampton Roads area school divisions (Hampton, Newport News and Suffolk) were engaged in an immersive, multi-platform STEM Education Engagement Program. In addition to this educational intervention, this collaborative team conducted a longitudinal, experimental research study that followed a cohort of students from 4th grade to the end of their 5th grade year. STEM 360 was a combined educational program and research initiative designed to influence the learning system of student participants. The goals of this initiative were to increase participants' STEM career awareness, academic achievement, engagement with STEM, and positive attitudes towards STEM. For the purposes of this study we defined the learning ecosystem as including:

The People:

- Classroom teachers- a lead teacher at each school
- VASC educators designated as STEM Coaches
- Parents
- Informal Science Educators at partner free-choice learning organizations (Virginia Beach iFLY (iFLY), East Coast Polytechnic Institute (ECPI), Norfolk Botanical Garden, Virginia Zoo, and the Virginia Seafood Agricultural Research and Extension Center- Virginia Tech (Virginia Tech))

The Designed Learning Experiences:

- Outreach programs conducted at the schools
- Field experiences at free-choice learning institutions
- VASC STEM Saturdays
- Email communication with parents/caregivers

Although clearly this did not represent the total possible STEM learning ecosystem, it did represent a learning ecosystem far larger than traditionally considered. The STEM 360 ecosystem provided all students with opportunities to engage with STEM experiences that were at least equal to what students commonly encounter as part of the public school education offered in this region. However, for those students in the randomly selected “moderate” and “high” level intervention schools, the STEM 360 Project created a learning ecosystem that was significantly enriched compared to what students in the region typically encounter as part of their usual educational offerings.

Program Overview

The STEM 360 Project explored how different levels of STEM learning enrichment influenced students’ STEM career awareness, academic achievement, engagement and attitudes. Four strategies were used to enhance the existing STEM learning environment: In-School Educational Outreaches, Field Experiences to VASC and other local informal STEM institutions, Family and Out-of-School Time Engagement through STEM Ambassadorship, and STEM Coach Engagement and Support.

In-School Education Outreaches were one hour programs conducted by VASC educators who had been identified as STEM Coaches. For example, one of the programs provided students with the opportunity to build model lunar colonies after learning about the Earth and Moon and the necessary design constraints needed to keep humans alive in such harsh environments. Over the course of two school years these programs addressed the following Virginia Standards of Learning: Science: 3.1, 3.5, 3.9d, 3.10, 3.11, 4.1, 4.4c, 4.5c, 4.8d, 5.1, 5.3, 5.4, 5.7a; History: 3.10.

Field Experiences provided opportunities to engage students in more immersive STEM learning opportunities– such as experiencing the MathAlive! Exhibition at VASC, indoor skydiving at iFLY as well as visits to the Norfolk Botanical Garden, Virginia Zoo, ECPI University, and Virginia Tech. Through team-based hands-on learning activities, IMAX educational films and guided educational experiences across year one and year two, the students engaged with the following Virginia Standards of Learning: Science: 3.3, 3.4b, 3.5, 3.6, 3.9d, 3.10, 3.11, 4.4, 4.5, 4.6, 4.8d, 4.9a-b, 5.5b-c, 5.7. In addition, field experiences in particular emphasized STEM careers. An experience matrix was designed by VASC to ensure the content was reinforced through each partner.

Norfolk Botanical Garden

- Plant Anatomy
- Flower Dissection
- Photosynthesis
- Pollination
- While at the Norfolk Botanical Garden students were introduced to careers such as conservationist, urban forester and planner, medical scientist, horticultural therapist, and agricultural extension agent.

Virginia Zoo

- Food Web vs. Food Chain
- Animal Adaptations
- Predator Prey Relationship
- Habitats
- While at the Virginia Zoo students learned about careers such as zoologist, animal dietitian, and habitat designer.

iFLY

- Principles of Flight
- While at iFLY students received the opportunity to indoor skydive in iFLY’s vertical wind tunnel.

ECPI

- Robotics
- Health Sciences
- Mechatronics
- Through hands-on investigation at ECPI students learned about health sciences with sonography and other STEM-related jobs including mechatronics, robotics, game development, and culinary arts.

Virginia Tech

- Habitats
- Aquaponics
- Hydroponics
- Students experienced a day in the life of an ichthyologist by observing and studying fish in their habitats.

Virginia Air & Space Center

- Educational IMAX Films
 - Hurricane 3D (Weather; Vegetation)
 - Amazon Adventure (Habitats, Mimicry)
- Mars Colony Program
 - Human habitats for space survival
- Magic Planet Program
 - Tectonic plates and their effect on habitats
 - Building sustainable structures for survival
- Meteorology and the importance of hurricanes to remove old vegetation to allow the environment to support new growth.
- Structural engineering to support human habitats for survival in harsh environments on Earth and in space.
- While at the Virginia Air & Space Center students learned about careers such as meteorologist, aeronautical engineer, structural engineer, astronaut, pilot, and geologist.

STEM Ambassadorship – students were enrolled in the STEM 360 VASC Ambassador Program which allowed for free unlimited entry to the Virginia Air & Space Center for each participating student and one adult. Biweekly STEM Saturday programs were offered at the museum featuring a wide variety of STEM activities based around a theme. In addition, guest speakers were often featured at these events. For example, during one STEM Saturday Apollo Astronauts Fred Haise, Lunar Module Pilot of the Apollo 13 mission and Walt Cunningham, Lunar Module Pilot of the Apollo 7 mission, were present to share stories and interact with VASC visitors. Other presenters included representatives of NASA, Huntington Ingalls Newport News Shipbuilding, the Tuskegee Airman Hampton Chapter, the United States Air Force, Hampton University, and ECPI.

STEM Coaches provided engagement and support for all participating schools. These VASC educators served as mentors to the students, conducted all in-school education programs and co-taught many field experiences for the students. The STEM Coaches also greeted students and families at STEM Saturdays, facilitated activities at STEM Saturdays and communicated with classroom teachers and parents about STEM opportunities in the community that connected to experiences provided in the program that might be of interest to students and their families.

Research Questions

- How and in what ways could a comprehensive suite of learning interventions – both in- and out-of-school - measurably improve STEM career awareness, academic achievement, engagement with and positive attitudes towards STEM?
- How and in what ways did the results vary as a function of the level of learning intervention participants experienced as part of the STEM 360 Project?
- What effect did gender and socioeconomic status have on the results?

Participants

Recruitment strategies were used to invite families to participate in this program and research study including: direct letters to parents, email communications, and in-person information nights held at all 20 participating schools. Given the challenges of parental engagement that are often observed in public school settings, the program anticipated there might be difficulty securing parental consent to participate in this research study. In an effort to equitably enrich the STEM experiences of all students in classrooms participating in this program, even if they did not have signed permission from parents, all students were included in all STEM 360 educational program experiences. However, only those students who had signed permission from parents were included in the research measures of the project. Over 1,800 4th grade students from Hampton, Newport News, and Suffolk school divisions were contacted about the STEM 360 Project. With the additional recruitment of students in year two, a total of 1,594 students completed informed consent and were enrolled in the study.

Study Design

Educational interventions were scheduled and delivered throughout the school year in order to be as responsive as possible to the academic calendar and were aligned with target science learning outcomes. Schools were randomly assigned to one of three levels of intervention within each of the three participating divisions:

- The Level 1 experience included: (1) Four field experiences to informal learning organizations, (2) four in-school outreach programs and connection with a proactive STEM Coach, and (3) membership at VASC for the duration of the study with an invitation and encouragement to attend biweekly STEM Saturday events at VASC.
- The Level 2 experience included: (1) Two field experiences to informal learning organizations, (2) two in-school outreach programs, with access to a STEM Coach, and (3) membership at VASC for the duration of the study, and an invitation to attend biweekly STEM Saturday events at VASC.
- The Level 3 experience included: One in-school outreach program.

In this design, Level 1 represented the maximum amount of engagement with STEM learning opportunities provided by the program, Level 2 represented an enriched amount of engagement and Level 3 represented a “typical” engagement between under-resourced public schools and science centers. The Level 3 experience was considered a control group in the analysis, as it provided a mechanism for the project to control for normal changes attributable to student maturation and other efforts going on in students’ lives (e.g., other school STEM-related activities, when assessing pre- to post-program changes in STEM-related outcomes).

All participants with parental consent completed baseline surveys during the 4th grade school year prior to experiencing any STEM 360 experiences. The survey was an adapted version of the Noyce Foundation and National Science Foundation supported Synergies Project instrument designed to measure STEM engagement, interest, and workforce awareness with items that measured frequency of participation in out-of-school STEM activities, youth’s perceived STEM knowledge, science self-concept, and perceptions of the value and relevance of science (cf., Falk, et al., 2016). Academic achievement was measured using the Commonwealth of Virginia’s Standards of Learning (SOL) scores (VDOE, 2018) and a project-specific set of measures administered as part of STEM 360-arranged school field experiences. All participants repeated surveys at the conclusion of the 4th grade school year either online or using pencil and paper. In year two of the study, all participants completed both baseline and end-of-the year surveys online at the end of the 5th grade school year.

There were 20 participating schools in year two of the study drawn from each of the three school divisions. Approximately a third of the study participants were drawn from each division. Within each school division, participating schools were randomly assigned to each of the three study levels (Table 1).

As a proxy for information related to participants’ socioeconomic status (SES), half of the participating schools had the majority of students qualifying for free and reduced lunch and were designated as Low SES, while the other half of participating schools had less than 50% of students qualifying for free and reduced lunch and were designated as High SES. It is important to note, that having 49% of a school population qualifying for free and reduced lunch is hardly

representative of a High SES school. Thus, in this report the terms High SES and Low SES should be interpreted as comparative terms not as literal terms.

The average age of participants at the start of this study was nine years old; with the youngest participants age eight, the oldest age eleven. At the end of year two, the average student age increased to ten years old; with the youngest participant's age nine, and the oldest age thirteen. There were 796 boys and 793 girls in the study. Nearly half of the participants self-identified as African American (52%), a third as white (29%), and less than 10% as Native American (6%), Latino (7%), Asian/Asian American (4%) and Native Hawaiian/Pacific Islander (2%). Age, gender, race and ethnicity were equitably distributed across the three study levels.

Table 1. Summary of Participant Schools by Division, Socioeconomic Status (SES), Level and Student Numbers

| | Elementary School | SES Group (H/L) | Level (1/2/3) | Number of Participating Students | Percent of Total Students |
|--------------------|----------------------|-----------------|---------------|----------------------------------|---------------------------|
| Hampton | Hunter B. Andrews | H | 1 | | |
| | Jane H. Bryan | L | 1 | | |
| | William Mason Cooper | H | 2 | | |
| | Paul Burbank | L | 2 | | |
| | Armstrong | H | 3 | | |
| | Captain John Smith | L | 3 | | |
| | George P. Phenix | H | 3 | | |
| Hampton Total | | | | 556 | 35% |
| Newport News | Hiddenwood | L | 1 | | |
| | B.C. Charles | H | 1 | | |
| | Lee Hall | H | 2 | | |
| | Epes | L | 2 | | |
| | Richneck | H | 3 | | |
| | George J. McIntosh | L | 3 | | |
| Newport News Total | | | | 485 | 30% |
| Suffolk | Nansemond Parkway | H | 1 | | |
| | Booker T. Washington | L | 1 | | |
| | Driver | H | 2 | | |
| | Pioneer | L | 2 | | |
| | Oakland | H | 3 | | |
| | Hillpoint | L | 3 | | |
| | Mack Benn, Jr. | L | 3 | | |
| Suffolk Total | | | | 553 | 35% |
| Total Enrollment | | | | 1,594 | 100% |

Methods & Findings

To explore the impact of the STEM 360 Project on students' STEM career awareness, academic achievement, engagement and attitudes we created composite variables to explore these constructs. For example, under the category of STEM career awareness we identified a set of items that measured STEM career aspirations. This was a combination of mean scores from the following five rating scales: I Would Like To Have A Job That Uses Math; I Would Like To Have A Job That Uses Science; I Would Like To Have A Job That Uses Technology; I Would Like To Have A Job Where I Can Build or Repair Things; I Would Like To Have A Job Where I Can Make, Design, or Invent New Things. Similarly, the composite measure for self-directed STEM activity engagement was a combination of mean scores from the following five rating scales: Visit a park or natural area; Garden or grow plants at home; Do science kits, experiments, or stuff like that at home; Watch a TV program about science, math, or technology; Build or take things apart or repair things; Solve puzzles or math problems.

As would be expected in an experimental design such as this, at the start of the STEM 360 Project there were a smattering of differences between Level 1, 2 and 3 students in their baseline STEM career awareness, academic achievement, engagement or attitudes, but no clear significant patterns that would suggest these populations were anything but comparable (for specifics see: Palmquist, Falk & Meier, 2017).

As in all applied research, there were challenges created by working in a dynamic and authentic learning system. While there was some observed variability in timing of experiences, fidelity of implementation across sites, and consistency with student attendance, these were to be expected when working within a real-world learning context involving multiple school divisions, schools, informal education organizations and of course parents and children. Overall, we are confident in the findings reported below and what they suggest about the impact of the STEM 360 Project on students' STEM career awareness, academic achievement, engagement and attitudes. Students across treatment levels produced significantly different patterns of responses for items related to STEM career awareness, academic achievement, engagement and attitudes. Selected findings are included that describe changes from pre- to post-program and the ways in which the study conditions related to each other at the end of the 5th grade school year.

STEM Career Awareness

The survey used a combination of rating scales and open-ended items to explore students' STEM career awareness. For this analysis, we defined STEM career awareness as the ability to name careers that use Science, Technology, Engineering and Math. In response to open-ended items, students self-generated as many career names as they could recall. In the area of career awareness, there were no significant differences between treatment levels detected on the baseline survey. Prior to the program, students who answered the question on average reported two STEM careers. Many students could not name a single STEM career, however the greatest number of STEM careers named on the baseline survey was seven. The most frequently reported careers were scientist, science teacher, doctor, meteorologist, math teacher, and video game maker. Many students also described jobs in which they might expect to use STEM without providing a label. For example: "A person who fixes or makes new technology", "People who go in space and study the sun, the stars, and how far all the planets are from the sun, and how far planets are from other planets, and how hot or cold the planets are."

At the conclusion of their 5th grade year, on average, all students in the study slightly increased their awareness of STEM careers (Pre-Program $M=2$ to Post-Program $M=4$). However, there were significant programmatic effects in the number of careers named by Level 1 as compared with Level 3 students. Although there were no significant differences between adjacent levels of students, e.g., between 5th grade Level 1 and Level 2 students and between 5th grade Level 2 and Level 3, there were statistically significant differences between the highest level of STEM 360 involvement, 5th graders in Level 1 schools and the control group of 5th graders in Level 3 schools ($t(1,556)=2.21, p<.001$). While there were still many Level 3 "control" students at the end of the two years of the project who could not name a single STEM career, the high involvement students in Level 1 STEM 360 schools could easily name multiple STEM careers. As opposed to a pre-program high of seven legitimate STEM careers listed by a single student, post-program one Level 1 student listed 42 legitimate STEM careers. While this individual was obviously an outlier, there were quite a number of Level 1 students who generated lists with more than ten STEM careers.

For example, one Level 1 student produced the following list of 12 careers:

- Doctor
- Oceanographer
- Physicist
- Geologist
- Veterinarian
- Engineer
- Mathematician
- Teacher
- Herpetologist (the study of amphibians)
- Zoologist
- Architect
- Cardiologist

Across student lists, careers like scientist, science teacher, meteorologist, math teacher, and doctor were most frequently mentioned. However, at the conclusion of the program, students, particularly those in Level 1 significantly increased the diversity and specificity of careers that they reported. For example, on the baseline a student might list “doctor and scientist” as STEM careers while on the post program survey they listed “cardiologist and botanist.” There were also some careers listed on the post program survey that were never mentioned on the baseline survey. For example, careers such as: forensic scientist, ichthyologist (study of fish), lepidopterist (study of moths and butterflies), forest pathologist, zoo habitat designer, and Virginia Air & Space Center staff member.

It is a fair inference that this kind of increased awareness and specificity of STEM careers was a direct result of the field experiences designed and delivered through the STEM 360 Project; again, this specificity was particularly striking in Level 1 student responses.

In addition, at the conclusion of the project, in response to open-ended questions related to careers, Level 1 students included comments that indicated that this group in particular had a significantly heightened awareness and understanding of the pervasive nature of STEM careers. Examples included:

- “STEM is used in every job there is.”
- “Almost every job in the universe. Like working at NASA, being a teacher, working with technology. Lots of jobs work with science.”
- “All jobs where you are finding out new things - those are science jobs.”

This set of responses is particularly encouraging as it suggests that students’ increased awareness of STEM goes beyond connecting it to specific careers and demonstrates the beginning of an appreciation that STEM skills are important more broadly for all careers.

Youth STEM career aspirations were also explored. As shown in Figure 1, analysis of composite student rating scales revealed that the students in Level 1 schools were significantly more interested in pursuing a career in STEM than the students in Level 3 schools ($F(2,1078)=2.95, p=.04$) at the conclusion of the STEM 360 Project. Although all students showed an overall increase in their interest in pursuing a career using STEM skills from the beginning of the program to the end of the program, students in Level 1 and Level 2 schools were more likely than those in Level 3 schools to recognize that STEM skills were used across a wide diversity of careers with comments like, “In almost all jobs I’ll need to use math and technology.” This overall increase in this awareness was statistically significant only for students in the Level 1 schools ($t(1, 218)=2.60, p=.01$).

Figure 1. Pre- to Post-Program Change in STEM Career Aspirations by Level

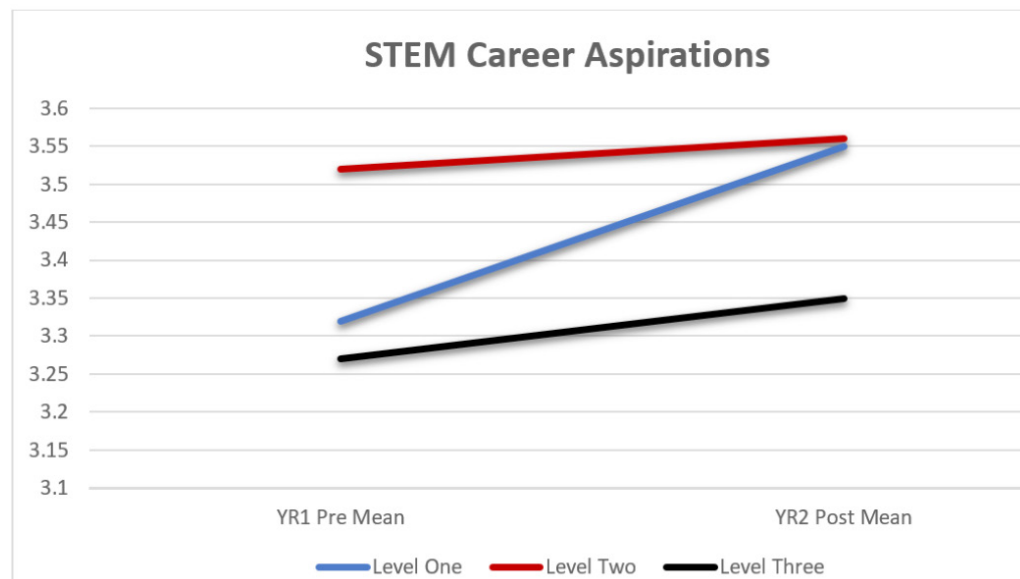


Figure 2. Word Cloud of Level 1 Students' Grade 5 STEM-Related Responses to the Question: "What do you want to be when you grow up?"



Over the two year study, participants in Level 1 schools attended four field experiences to VASC and four to our free-choice learning partners. Participants in Level 2 schools attended two field experiences to VASC and two experiences to our free-choice learning partners. Both Level 1 and Level 2 school students took short pre/post-experience surveys before and after each field experience. These pre/post-experience surveys were designed to test changes in students' knowledge

of content presented in each of the experiences. Pre- and post-experience surveys were identical, and each contained a set of closed-ended, multiple choice questions. The number of correct answers were totaled and then divided by the number of total questions on the pre/post- experience surveys to create a score for each participant from 0 to 1 (1 being a perfect score). Independent sample t-tests were used to assess differences between pre- and post-group mean scores, both within and between experience levels (Table 2).

Table 2: Student Pre- and Post-Experience Surveys Score Comparisons by Level

| Trip | Level | Pre Mean | Post Mean | Difference | P-Value |
|---|-------|----------|-----------|------------|---------|
| Zoo | 1 | .61 | .71 | .10 | .001 |
| Zoo | 2 | .62 | .64 | .02 | .539 |
| Difference | | -.01 | .07 | | |
| P-Value | | .792 | .019 | | |
| Garden | 1 | .51 | .67 | .16 | .001 |
| Garden | 2 | .37 | .40 | .03 | .464 |
| Difference | | .14 | .27 | | |
| P-Value | | .001 | .001 | | |
| VASC 1* | 1 | .43 | .86 | .43 | .001 |
| VASC 1* | 2 | .70 | .57 | -.13 | .011 |
| Difference | | -.27 | .29 | | |
| P-Value | | .001 | .001 | | |
| VASC 2* | 1 | .64 | .73 | .09 | .005 |
| VASC 2* | 2 | .64 | .74 | .10 | .005 |
| Difference | | .00 | -.01 | | |
| P-Value | | .997 | .825 | | |
| * VASC 1= Earth Science, VASC 2= Habitats | | | | | |

Student SOL scores were provided to the project by each school division. There is no standardized testing for science in Virginia until the 5th grade. Therefore we were limited to two types of comparisons. We could compare 5th grade students' science SOL scores as a function of level in 2017/2018, after all had completed participation in the STEM 360 Project. The second way we could compare students is both overall and by level across years. However for these latter comparisons we only had pass/not pass scores for the 2015/2016 and 2016/2017 school years since we did not have Institutional Review Board (IRB) approval for students from earlier year.

We began by looking at individual scores for STEM 360 students at the end of the 2017/2018 school year. We compared 5th grade students' mean Science SOL scores as a function of the type of STEM 360 intervention they received, i.e., Level 1 Science SOL scores versus Level 2 Science SOL scores, Level 1 Science SOL scores versus Level 3 Science SOL scores and Level 2 Science SOL scores versus Level 3 Science SOL scores. The appropriate statistical test for this kind of assessment is a one-way analysis of variance (ANOVA) test. There was an overall significant difference in Science SOL test score group means as a function of level ($F(2, 1,184) = 5.13, p < .05$). Science SOL test score group means increased from experience Level 3 ($M = 439.17, SD = 65.32$) to experience Level 2 ($M = 444.26, SD = 64.96$) to experience Level 1 ($M = 453.23, SD = 65.29$). An additional statistical test, Tukey's post hoc analysis, confirmed that the increase in scores between students in Level 1 as compared to students in Level 3 was statistically significant ($14.06, SE = 4.4, p = .004$).

Table 3. Aggregate Percentage of Level 1 5th Grade Students Passing the Science SOL Tests by School Year and Gender

| School Year | 2015-2016 No STEM 360 | 2016-2017 No STEM 360 | 2017-2018 STEM 360 Phase 1 |
|----------------|--------------------------|--------------------------|-------------------------------|
| Science All | 75 | 75 | 78 |
| Science Male | 77 | 72 | 82 |
| Science Female | 74 | 78 | 75 |

Tables 3, 4, and 5 report the aggregate percentage of 5th grade students passing the Science SOL tests in each of three school years. The 2015/2016 school year represents scores before any STEM 360 programming would have been introduced into these three school divisions. The 2016/2017 scores represent 5th graders who were not part of the STEM 360 Project but since their schools would have been engaged STEM 360 programming it was theoretically possible that some effects “bled” into this cohort. Finally the 2017/2018 scores represent students who fully participated in the STEM 360 Project. Gender and STEM 360 Level of engagement are also included in the tables below.

Table 4. Aggregate Percentage of Level 2 5th Grade Students Passing the Science SOL Tests by School Year and Gender

| School Year | 2015-2016 No STEM 360 | 2016-2017 No STEM 360 | 2017-2018 STEM 360 Phase 1 |
|----------------|--------------------------|--------------------------|-------------------------------|
| Science All | 75 | 76 | 81 |
| Science Male | 75 | 80 | 80 |
| Science Female | 77 | 76 | 83 |

Table 5. Aggregate Percentage of Level 3 (control group) 5th Grade Students Passing the Science SOL Tests by School Year and Gender

| School Year | 2015-2016 No STEM 360 | 2015-2017 No STEM 360 | 2017-2018 STEM 360 Phase 1 |
|----------------|--------------------------|--------------------------|-------------------------------|
| Science All | 81 | 80 | 72 |
| Science Male | 81 | 79 | 70 |
| Science Female | 83 | 80 | 73 |

It was not possible with just these aggregate “passing scores” to meaningfully calculate significance levels for the data summarized in Tables 3, 4 & 5, but on face value it appears that Level 1 students, and boys in particular, showed overall increases in their Science SOL scores. Level 2 students, and girls in particular, also appeared to show improvement in their Science SOL scores.

The results shown in Table 5 suggest that Level 3 students’ 2017/2018 Science SOL scores overall, as well as for both genders, declined relative to previous years, years before the STEM 360 Project began. If this apparent decline in Science SOL scores between 2015/2016-2016/2017 and 2017/2018 was actually significant, which we do not know, combined with the fact that the Science SOL scores of Level 1 and Level 2 students in 2017/2018 were significantly higher than Level 3 students, which we do know is true, it would provide additional evidence of the impact of the STEM 360 Project on student science achievement.

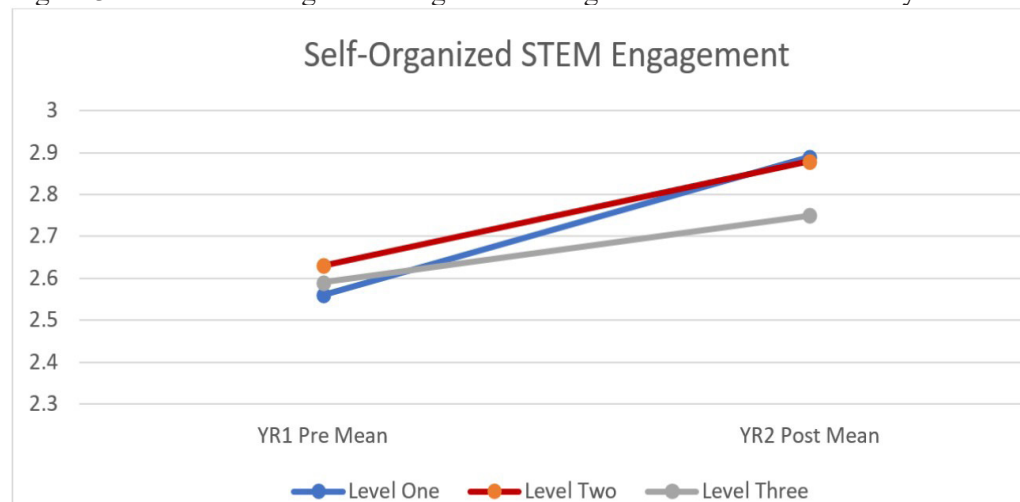
Further analysis, based just on 2017/2018 scores, was conducted to look for effects related to SES and gender. Overall, SES (as measured in this study) did not have a statistically significant effect on mean Science SOL scores in 2017/2018, but there were some Level effects found. A one-way ANOVA test of all participants divided into one of six experience levels – 3 Levels X Low/High SES – indicated that Science SOL test score group means were statistically significantly different between the six groups ($F(5, 1,181) = 13.87, p < .001$). Tukey’s post hoc analysis revealed that these differences were likely due to the high scores of Level 1 students. Both the Level 1 “High SES” ($M=461.20, SD = 64.57$) group mean scores and the Level 1 “Low SES” ($M=444.18, SD = 65.10$) group mean scores were statistically higher than the other groups, including the Level 2 “High SES” ($M=421.80, SD = 57.77$) group mean scores. There were no statistically significant gender differences observed.

STEM Engagement

The survey used a set of rating scales to explore how often students participated in STEM activities. Two types of participant STEM engagement were measured: self-organized activities like watching a TV program about STEM topics or building and taking things apart at home and program-organized activities like visiting a science museum or participating in Scouts or 4H.

At the conclusion of the STEM 360 Project, analysis of composite responses revealed that students across all three levels significantly increased their participation in self-organized STEM activities. However, there were no significant differences across levels. As illustrated in Figure 3, Level 1 students demonstrated the largest gains from pre-program ($M=2.56$) to post-program ($M=2.89$) ($t(244)=4.93$, $p=.001$), followed by Level 2 students pre-program ($M=2.63$) to post-program ($M=2.88$) ($t(214)=3.13$, $p<.002$), and lastly by Level 3 students pre-program ($M=2.59$) to post-program ($M=2.75$) ($t(195)=2.40$, $p<.02$).

Figure 3. Pre to Post-Program Change in Self-Organized STEM Activities by Level

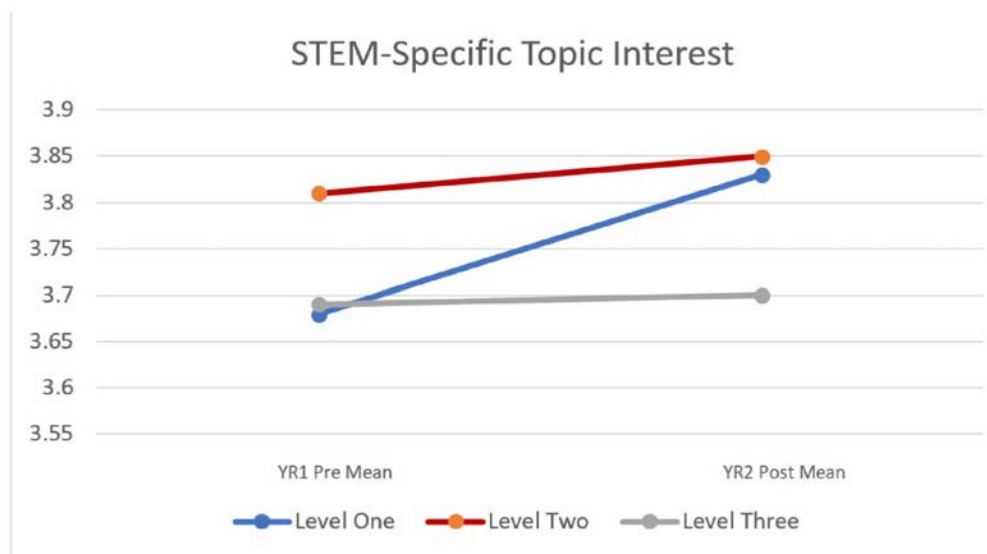


Across all the various types of group-organized STEM activities surveyed, there were no significant differences in engagement reported across the three treatment groups ($F(2,1143)=0.83$, $p=.44$). However, there were significant differences reported in the frequency of visiting science museums across study conditions with Level 1 students reporting visiting a science museum significantly more often than Level 3 students ($F(2,1137)=0.84$, $p<.001$). The same pattern was observed in relation to visiting a zoo with Level 1 students reporting visiting a zoo significantly more often than Level 3 students ($F(2,1137)=4.50$, $p<.05$). These results were likely a direct consequence of the school field experiences offered through the STEM 360 Project.

STEM Attitudes & Interest

The survey used two approaches to explore attitudes and interest towards STEM: (1) ratings of interest in specific STEM topics (e.g., "I'm interested in space exploration, weather, and how the human body works") and (2) general ratings of attitudes towards Science, Technology, Engineering and Math (e.g., "I'm interested in science"). As shown in Figure 4, participation in STEM 360 significantly increased Level 1 students' STEM-specific topic interests from the beginning of the program ($M=3.68$) to the end of the program ($M=3.83$) ($t(222)=2.01$, $p<.05$). Students in Level 2 and Level 3 also showed slight increases in their STEM-specific topic interests, but this change was not statistically significant from the beginning of the program to the end of the program.

Figure 4. Pre- to Post-Program Change in STEM-Specific Topic Interests by Level



Taking a closer look at this pattern, it seems that math topic interests (e.g. solving puzzles) and biology topic interests (e.g. how the human body works) may have accounted for these general STEM topic interest changes. Students in Level 1 schools significantly increased their interest in math topics from pre-program ($M = 3.09$) to post-program ($M = 3.38$) ($t(222) = 3.07, p = .002$). Students in Level 2 and Level 3 schools also increased their math topic interests, but these changes were not statistically significant from the beginning of the program to the end of the program. Finally, all students significantly increased their biology topic interests from pre-program to post-program.

In contrast, when we examined general attitudes towards STEM, average ratings for interest in Science, Technology, Engineering, and Math declined from pre-program to post-program across all three groups, though the average ratings declined the least for the students in Level 1 schools. In general, these patterns suggest that increased exposure to STEM topics and activities as occurred at Levels 1 and 2 increased interest and positive attitudes towards these specific STEM-related experiences, but there was significant variability in the data which effected results and significance levels.

Meanwhile, on overall attitudes towards Science & Technology as a general topic area, levels of interest remained relatively flat for all three groups. The mean change and slope was essentially unchanged and identical for Levels 2 and 3 ($M = 3.85, 3.85$ pre-program to $M = 3.84, 3.86$ post-program) while Level 1 students showed a very slight, but insignificant increase pre- to post-program ($M = 3.84$ pre-program to $M = 3.90$ post-program).

The Role of Gender and Socioeconomic Status

Overall, there was evidence of some gender-related differences in the data across three of the four outcome areas – career awareness, engagement and STEM attitudes. These specific instances of differences between boys and girls are noted below.

In the area of career awareness, a key difference was that by program’s end, girls in the Level 1 and Level 2 treatment groups were significantly more likely to express an interest in pursuing a STEM career than boys (Level 1 - $X^2 = 13.06, df = 1, p < .005$; Level 2 - $X^2 = 15.47, X^2 = 13.06, df = 1, p < .005$).

In the area of academic achievement, although there appeared to be very modest gender differences in the aggregate SOL “passing” science achievement scores, there is no basis to indicate whether these apparent differences were statistically significant. No significant gender differences emerged in our analysis of the 2017/2018 data.

There were indications that gender might have been a factor in post-program patterns of STEM engagement, specifically

in solo STEM activities. It appears girls in Levels 2 and 3 did more STEM-specific individual activities than boys. For example, females watched more STEM-related TV programs than males and also indicated higher frequencies of engagement in activities such as building and taking things apart at home. Although potentially interesting, these isolated findings may or may not be indicative of true patterns or may just be noise in the data.

At the conclusion of the program, gender seemed to impact general interest in STEM-specific topics for students in Level 1 and Level 2 schools, but in opposite ways. In Level 1 schools, boys ($M = 3.97$) expressed significantly more general STEM topic interest than girls ($M = 3.78$) ($F(1,427) = 5.60$; $p < .02$). In contrast, in the Level 2 schools, girls ($M = 3.89$) were significantly more likely to express a general STEM topic interest than boys ($M = 3.70$) ($F(1,427) = 5.21$; $p < .05$). Gender also emerged as a factor in post-program patterns of general attitudes towards science and technology. For students in Level 1 schools, boys ($M = 4.04$) expressed significantly more interest in science and technology than girls ($M = 3.75$) ($F(1,433) = 10.29$; $p < .002$).

Despite evidence that gender may have played a role in these various outcomes, the results are anything but clear-cut and unidirectional. In some areas girls seemed to have better results, while in other areas boys did.

Except as noted in the one instance relative to 2017/2018 SOL Science scores, post-program analysis of socioeconomic status as measured by schools with higher levels of free and reduced lunch eligibility as compared with schools with lower levels of free and reduced lunch eligibility did not emerge as a significant effect. And even in this case, the difference appeared to be that Level 1 students, regardless of SES performed better than others. In the outcome areas of student STEM career awareness, academic achievement, engagement and attitudes towards STEM, there was no significant evidence of an SES effect (NOTE: again, as measured in this study).

Discussion

Year one focused on designing and engaging students with high quality STEM educational experiences and support during their 4th grade school year. Year two of the program focused on refining these cross-ecosystem STEM learning opportunities to maximize the impact on student outcomes by the end of the 5th grade school year. Analyses explored the following questions:

- How and in what ways could a comprehensive suite of learning interventions, both in- and out-of-school, measurably improve STEM career awareness, academic achievement, engagement with and positive attitudes towards STEM?
- How and in what ways did the results vary as a function of the level of learning intervention participants experienced as part of the STEM 360 Project?
- What effect did gender and socioeconomic status have on the results?

In reviewing findings it needs to be noted that in many of the schools, we were made aware by our school partners that STEM 360 was not the only STEM enrichment program being implemented. These additional programs were operating totally independent of our random assignment of schools to treatment Levels 1-3. For example, some Level 3 schools, but not all, were receiving additional in-school STEM programming over the course of the study. The additional programming in some cases may have even equaled or exceeded the in-school STEM programming of some of our Level 1 schools. Although we understand this is just part of the challenge of doing this kind of research in the real world, this “noise” in the system obviously contributed to an increase in variability in the data; variability that potentially masked some of the effects created by the STEM 360 interventions.

It should also be noted that over the course of this inaugural “test” of the STEM 360 Project, initial implementation of the four key facets of the program – in-school educational outreaches, field experiences to VASC and other local STEM-related free-choice learning institutions, family and out-of-school time engagement, and STEM coach engagement and support – were uneven. By the end of the year two, all four strategies were fully engaged and working well. But this ramping up of implementation involving the participation and cooperation of multiple school divisions, individual

schools, and informal institutions and their respective administrators and on-the-ground facilitators, though normal for a complex effort such as this, undoubtedly also effected outcomes. Yet, despite this “noise” the results are surprisingly strong.

At the close of the 2017-2018 school year all 5th grade students from each of the three Hampton Roads area school divisions (Hampton, Newport News, Suffolk) who participated in the STEM 360 Project demonstrated some measure of benefit. Improvements were seen across all four of the program’s key outcomes – STEM career awareness, Science academic achievement, STEM engagement, and attitudes towards STEM – and in some measure by all levels of participation. As expected, students in the Level 1 treatment group overall – the group with the greatest quantity and quality of program interventions – showed the best results, though there were certainly significant gains by students in the intermediate intervention group – Level 2. **Data suggests that the answers to the first two research questions were yes.**

- **The comprehensive suite of learning interventions – both in- and out-of-school – of the STEM 360 Project measurably improved students’ STEM career awareness, academic achievement, engagement with and positive attitudes towards STEM.**
- **Level of support made important differences; students receiving the highest level of STEM 360 Project support (Level 1) showed significantly greater improvements in all four outcome areas than students receiving less (Level 2) or minimal support (Level 3).**

STEM 360 Increased Students’ STEM Career Awareness

There were two types of items that measured career awareness: those that explored connections between subject areas and future careers (e.g., I would like to have a job that uses science) and those that asked students to generate examples of career types that use STEM skills (e.g., List as many jobs as you can that use science). At the conclusion of the STEM 360 Project, analysis of composite student rating scales revealed the students in Level 1 schools were significantly more interested in pursuing a career in STEM than the students in the control schools of Level 3. In addition, students in the Level 1 schools also significantly increased their interest in pursuing a career using STEM skills from the beginning of the program to the end of the program. While students in Level 2 and 3 schools also demonstrated increases, these changes were not significant. While all students seem to gain increased awareness of the value of STEM content across study levels, it was clear that students in Level 1 schools made greater gains after two years in the STEM 360 Project than the students in the other two treatment levels. It is likely that the increased emphasis on STEM careers infused throughout field experiences and classroom outreaches produced a cumulative effect for these Level 1 students.

In addition, on the baseline measure, students across all levels had difficulty identifying more than one example of a career that utilized Science, Technology, Engineering, or Math. At the conclusion of the program, Level 1 and 2 students were capable of listing numerous jobs that utilized STEM skills and there was a significant increase in the diversity of STEM careers they could recall. On the final survey, both Level 1 and 2 students, but particularly Level 1 students, generated STEM career lists that included examples like: aerospace engineer, astronaut, pilot, chemist, biologist, botanist, horticultural therapist, architect, electrician, computer scientist, FBI agent, computer programmer, robotics engineer, astrophysicist, app developer, and cybersecurity worker. Many of these careers were specifically featured in STEM 360 field experiences and outreach programs.

Finally, students were also asked, “What do you want to be when you grow up?”. While all students demonstrated a significant increase in STEM career aspirations, only Level 1 students demonstrated a significant change from the beginning of the program to the end. While doctor, veterinarian, and scientist remained the most frequently listed occupations, there was both an increased diversity of careers reported at the conclusion of the program and a larger percentage of students who reported an interest in pursuing these careers. At the conclusion of the program, students in both Level 1 and Level 2 schools, but again particularly in Level 1 schools were much more likely than those in Level 3 schools to recognize that STEM skills were used across a wide diversity of careers with comments like, “In almost all jobs I’ll need to use math and technology.”

Taken together, all these lines of evidence indicate that the STEM 360 Project increased student STEM career awareness and aspirations. However, it was clear that the greatest impact occurred in the Level 1 students who received the highest level of cross-ecosystem STEM learning opportunities. The first phase, which focused on explicitly infusing career information into field experiences as well as classroom enrichment, clearly paid off. This approach should be continued during the replication phase.

STEM 360 Increased Student STEM Academic Achievement

Data from pre/post-experience surveys designed to determine if the school field experiences resulted in any significant short-term learning consistently showed that in most cases, positive increases in learning did occur. In the final year of the project, participants in Level 1 schools attended four field experiences to VASC and other local informal STEM institutions and participants in Level 2 schools attended two different field experiences. Level 1 schools' participants showed statistically significant increases in their understanding of content presented during field experiences for all four programs. Level 2 school participants showed statistically significant increases in their understanding of content presented during field experiences for all two programs. Results suggested that although Level 1 and Level 2 students were exposed to similar field experience content, the other complementary experiences provided to Level 1 students resulted in this group getting more out of their field experiences. This finding was reinforced by the fact that overall, Level 1 school participants scored significantly higher than Level 2 school participants on the exact same post-experience surveys.

Perhaps most importantly, there was strong evidence that participation in the STEM 360 Project affected science achievement. Level 1 students scored significantly higher than Level 2 students on their Science SOL tests, and Level 2 students scored significantly higher than Level 3 students. Although not conclusive since we did not have sufficient data to perform statistical tests, there was evidence that Level 1 and Level 2 STEM 360 participants benefited academically from the program as shown by their improvements in end of 5th grade year standardized SOL Science test scores. Perhaps most revealing was that in the 2017-2018 school year, Level 3 5th grade students' performance on their Science SOLs actually declined relative to previous years, though again we do not have sufficient data to know if this decline was statistically significant. The fact that these Level 3 "control" students appeared to have decreasing science achievement, despite other in-school science programs, while their peers in Levels 1 and 2 who were more fully engaged in the STEM-related experiences of STEM 360 were actually showing increases in Science SOL scores, represents additional evidence that the STEM 360 Project was influencing student achievement.

The STEM 360 Project intends to be even more explicitly focused on SOLs in the next replication phase of the project. This increased focus should further reinforce the benefits of STEM 360 on achievement evidenced in these first two years. Despite the clear benefits that full implementation of the STEM 360 Project afforded to Level 1 and 2 students in science, we did not specifically investigate the impact of the STEM 360 Project on mathematics achievement. Mathematics should be an area of increased focus in the next phase of the project.

STEM 360 Increased Student STEM Engagement

At the beginning of the study, students were administered a survey to measure their current levels of STEM engagement. Analysis suggested that for the majority of items, students across study levels significantly changed their patterns of STEM engagement, but there were no clear differences as a function of the three STEM 360 intervention levels. Because of the design of the study, our assumption was that if we saw comparable, positive changes in all groups, including Level 3 students, then it was likely the cause of these changes was attributable to normal processes such as maturation of the students or even events in the external world, rather than STEM 360 Project interventions. Of course, this is an inference and we cannot, based on the data we have, say why there were no cross-level differences. Further, it is worth noting that although student engagement with individualized STEM-focused activities improved overall, pre- to post-program, in general students in the study, regardless of level, were at best only moderately engaged in out-of-school, individualized STEM-related experiences. In other words, all students in the STEM 360 Project had considerable room for increased engagement. Although Level 1 students showed the greatest relative gains in their out-of-school, individualized STEM engagement, the lack of significance between levels suggests that the STEM 360 Project itself was not making as large an impact on this particular outcome as would have been liked.

On the other measure of engagement, group-organized engagement, there was clear evidence that the STEM 360 Project influenced the outcomes. Level 1 students were significantly more likely to report participating in organized visits to science museums and zoos than were either Level 2 or Level 3 students. Although this was no doubt directly due to the design of the study i.e., that Level 1 students had more field experiences than either Level 2 or Level 3 students, it is not insignificant. The lack of visits to these kinds of settings by students in Level 2 and particularly Level 3 suggests that if it were not for the STEM 360 Project, students in these school divisions would not typically be engaging in these kinds of activities at all.

As briefly summarized in the Introduction of this report, research has shown that there is a strong correlation between youth visits to STEM-related informal/free-choice education institutions and STEM literacy (Falk, et al., 2016a; Falk, et al, 2018; Falk & Needham, 2013). Thus, as a result of the STEM 360 Project, students in Level 1 schools were experiencing a significantly enriched STEM learning environment as compared with other students at similar schools. Outside of the structured activities afforded during school time, Level 1 students were no more likely than their peers to engage in such enriching activities. This latter area too should be an area to focus additional attention in the next phase of the project. This is an area where the easily managed interventions, i.e., enhanced in-school educational outreaches and field experiences to VASC and other local STEM-related free-choice learning institutions, were insufficient to move the dial. In the coming years the project will need to redouble its efforts to intervene with students through mentors and activation of parents in order to make any significant progress in this outcome area.

STEM 360 Increased Students' Attitudes Towards and Interest in STEM

There were two types of items that focused on STEM attitudes and interest – those that explored specific topic interests (e.g., “How much do you like finding out about mixing materials to see what happens?”, “How much do you like finding out about what it is like on other planets?”) and those that measured more general attitudes and interests (e.g., “I find science really interesting”). As with other baseline measures, there were no significant differences across study levels at the beginning of the study for students’ attitudes towards STEM and their general interest in science. However, the data suggest that participation in STEM 360 significantly increased Level 1 students’ overall STEM topic interests from the beginning of the program to the end of the program. Students in Level 2 and Level 3 also showed increases in their STEM topic interests, but these changes from the beginning of the program to the end of the program were not statistically significant.

Taking a closer look at this pattern, it seems that math topic interests (e.g., solving puzzles) and biology topic interests (e.g., how the human body works) may have accounted for much of the observed changes in STEM topical interest. Students in Level 1 schools significantly increased their interest in math topics pre-program to post-program while students in Level 2 and Level 3 schools did not. Meanwhile, interest in biology topics increased across all levels, with students showing significant increases from pre-program to post-program in this area, again led by Level 1 students.

However, unlike many national and international studies (see Introduction) but consistent with the longitudinal findings of the Synergies project (cf., Falk, et al., 2016b) for this age group, general attitudes towards STEM remained roughly stable from pre-program to post-program across all three levels. However, though not significant, the slight uptick in average ratings for Level 1 students suggests that the STEM 360 project might have played some moderate “buffering” role on student attitudes towards STEM generally at this critical age level. This too, is an area that also would be worth paying increased attention to in the next phase of the project. Like engagement, research has shown that students’ perception of whether their parents and other significant adults consider STEM important to their future, plays a critical role in youth themselves having these attitudes (DeWitt, et al., 2011; Falk, et al., 2016a). Thus, attitudes towards STEM, like engagement, would benefit from enhanced efforts by mentors and activation of parents if the project is to make any significant progress in this outcome area.

Finally, we come to the last research question, whether gender and socioeconomic status had any effect on outcomes. As stated earlier, there was no significant evidence of a consistent effect for either gender or SES. Post project analysis suggested that gender did emerge as a significant variable across three of the four broad outcome categories, but there were no consistent gender-related patterns, i.e., girls always better than boys or boys always better than girls, and what patterns we did see were limited and sporadic. For example, girls in the Level 1 and Level 2 treatment groups were significantly more likely to express an interest in pursuing a STEM career than boys, but boys superficially appeared to do better than girls on their SOL science achievement scores. While girls, in Levels 2 and 3 did more STEM-specific individual activities than boys, Level 1 boys expressed significantly more general interest in STEM topics than did girls and the opposite was the case at Level 2, with girls expressing significantly more STEM interest than boys. Although the program needs to be vigilant that gender is not an issue and that equitable opportunities are provided for both girls and boys, at the end of the day, it was hard to conclude from existing data that gender was a determining factor in outcomes.

The same could be said for socioeconomic status, though as will be noted below, we need to be more cautious in this conclusion. Except as noted in the one instance relative to SOL scores where both High and Low SES Level 1 students did better than even Level 2 High SES students, post project analysis of socioeconomic status as measured by schools with High levels of free and reduced lunch eligibility as compared with schools with Low(er) levels of free and reduced lunch eligibility did not emerge as significantly affecting measured outcomes of student STEM career awareness, academic achievement, engagement, attitudes or interest. However, the lack of evidence of SES differences may be a consequence of the fact virtually ALL of the students in these schools are from relatively low SES backgrounds. Hence, our somewhat arbitrary cut-off point of saying schools with less than 50% of their students on free or reduced lunch indicated a “High SES” school may have masked real differences. **Data suggests that the answers to the final research questions was likely no, but we cannot state this conclusion with certainty.**

- There was no clear evidence that either gender or SES (as defined in this study) strongly influenced the STEM 360 Project outcomes of changing students’ STEM career awareness, academic achievement, engagement and/or attitudes and interest.

Conclusions

Clearly all of the students in this study, whether Level 1, 2 or 3, were subject to a range of experiences beyond the interventions created by the STEM 360 Project. However, despite these “externalities” that complicated and may have at times actually obfuscated results, the preliminary results from this multi-pronged, ecosystem-level approach to enhancing STEM education opportunities were extremely positive. **This preliminary study provides strong evidence that when key literature-identified “levers” of influence are activated – enhanced in-classroom experiences, increased out-of-school informal learning experiences, key support from adult mentors and heightened family participation and engagement – students’ STEM career awareness, achievement, engagement, and attitudes can be significantly enhanced.** As hypothesized in the Introduction, the STEM 360 Project begins to demonstrate the wisdom of investing a community’s resources in not a single, primarily school-focused solution, but rather in a more community-wide, symbiotic approach to STEM education. Results overwhelmingly indicated that this STEM 360 Project approach, particularly at the most intense level of implementation (Level 1), significantly improved students’ STEM career awareness, achievement, engagement and attitudes towards STEM.

Although it took a while to fully activate all the “cylinders” of this multipronged STEM education effort, by year two, the STEM 360 team was able to “engage” all of the various partners in synergistically supporting student needs and building a concerted and coordinated STEM educational effort across all four parts of the program. And in so doing, the team was able to develop a suite of student STEM experiences that complemented, enhanced and extended students’ standard classroom instruction. As a result of this strategic collaboration between formal and informal educators, as well as the increased time in the program, the STEM 360 has demonstrated significant promise as a viable model for how Virginia and other states should conduct STEM education. It is a non-trivial accomplishment that the STEM 360 Project was able to demonstrate significant improvements in all four of the project’s key outcome areas – STEM career awareness,

science achievement, STEM engagement, and attitudes towards STEM and interest for what is arguably a cohort of some of Virginia's underserved students. This was not an experiment in a middle-class community, for youth of privilege. The subjects in this study were disproportionately minority youth, most with significant learning and economic challenges. The fact that this initial trial of the STEM 360 model was successful with this challenging population is particularly noteworthy.

Although it clearly was successful, it must be viewed as just an initial effort to implement and assess this approach. We are currently in year one of phase two of the STEM 360 Project; again being implemented in the same three school divisions – Hampton, Newport News and Suffolk. Although there is still likely to be “noise” in our data, we have made significant progress in damping much of it down. We believe that we will see even greater gains in the outcome areas of STEM career awareness, STEM achievement, STEM engagement and STEM attitudes and interests in this second iteration as all parties involved – school teachers and administrators and informal education staff and mentors – now have worked out most, if not all, of the initial logistical “kinks” and “glitches” endemic to implementing such a complex, multi-institution and multiple party experiment. We are confident in the value of STEM 360 and committed to supporting the improvements in Virginia's students that this project is delivering.

Though clearly that is a critically important outcome, this experiment in community STEM education has implications beyond the benefits to students. The STEM 360 Project equally has implications for the institutions involved in it's implementation. The Virginia Air & Space Center was the key driver behind this effort with strong collaboration from the three Hampton Roads area school divisions of Hampton, Newport News and Suffolk, and the other informal education institutions: iFLY, Norfolk Botanical Garden, ECPI University, Virginia Tech, and Virginia Zoo.

Starting with the Virginia Air & Space Center, VASC's board and supporters are beginning to see VASC in a new light. Rather than merely being perceived as a nice attraction and place to take children on field trips or weekends, the Virginia Air & Space Center is increasingly being seen as a regional and statewide leader in STEM education; an organization helping to address and solve the area's critical issues. This successful new direction for the Virginia Air & Space Center's future is creating new leadership opportunities by repositioning the relationship to both Virginia's school divisions and our sister free-choice learning institutions in the area.

Meanwhile for VASC's school and informal education partners, STEM 360 will forever change how they will view their educational efforts. Once it has been demonstrated that significant advantage accrues to organizations that forge meaningful shared partnerships in the pursuit of student learning, it is hard to go backwards and retreat into the insular approach that was the historical “norm” across Virginia and the rest of the nation. Each of the school division superintendents need to be commended for their courage and leadership; it is not easy to eschew the traditional school-first approach in the face of increasing scrutiny over how school time and resources should be spent. It is not easy to commit resources to taking students out of the classroom nor easy to assume the risk of failure. It will remain challenging, but now that this initial experiment has proven so successful, each successive effort will be easier.

And successive efforts there will be. The initial STEM 360 Project was funded through the Legislature of the Commonwealth of Virginia and as a result of the success, the project has received two additional years of funding. In collaboration with the same three Hampton Roads area school divisions (Hampton, Newport News and Suffolk) and the same core of free-choice learning education partners (iFLY, ECPI, Norfolk Botanical Garden, Virginia Zoo and Virginia Tech), the Virginia Air & Space Center and the Institute for Learning Innovation have initiated a second round of programming and assessment to determine if the findings can be replicated and validated with a new cohort of students. We are optimistic that this second effort will equal, or hopefully exceed, these initial positive outcomes.

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What our School Partners are Saying

"STEM 360 is an excellent resource for our students. Through field experiences, in-school programming and family engagement activities, students in Newport News Public Schools are becoming more interested in STEM and are experiencing significant gains in achievement. The STEM 360 Project is a great example of how collaborative, strategic partnerships can impact the learning capacity for all students."

Dr. George Parker, III, Ph.D.

Newport News Public Schools Superintendent

"Asking every typical 4th and 5th grader what they want to be when they grow up you get football player, basketball player, actress, and singer. So, the fact that different occupations and careers, and just different avenues of thinking, were brought into their lives through the STEM 360 Project has opened huge doors for these kids."

Kimberly Neirman

Suffolk City Schools Academic Coach

"When you think of the free-choice learning environment, like the Virginia Air & Space Center, it's so important that our young people have access to these opportunities, whereby they can deepen their knowledge and also make relevant connections as to what's going on in the classroom."

Dr. Jeffery Smith, Ph.D.

Hampton City Schools Superintendent

"STEM 360 has given students the opportunity to experience Science, Technology, Engineering and Math in a fun and engaging way rather than reading about it. Because of these experiences, classroom learning becomes real and students are able to make connections to a variety of careers."

Adia Charley

Newport News 5th Grade Teacher

"The STEM 360 program continues to provide rich and authentic learning experiences for both our students and teachers. It is truly a benefit to witness our students deeply engaged in real-world experiences, and excited about the prospect of pursuing careers in STEM."

Dr. Deran Whitney, Ph.D.

Suffolk Public Schools Superintendent

WATCH THE DOCUMENTARY:
www.vasc.org/stem360

ABOUT US

This research study is the result of a collaborative effort by the Virginia Air & Space Center, the Institute for Learning Innovation, Hampton City Schools, Newport News Public Schools, and Suffolk Public Schools.

VIRGINIA AIR & SPACE CENTER

NASA LANGLEY
VISITOR CENTER



The Virginia Air & Space Center is the lead institution for the STEM 360 Project. It serves the Hampton Roads region by delivering fundamentally relevant and essential STEM content to both families and school divisions. The mission of the Virginia Air & Space Center is to educate, entertain, and inspire explorers of all ages.

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INSTITUTE FOR
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The Institute for Learning Innovation believes that a broader definition of learning, one that is lifelong and free-choice, can offer solutions to many of the critical problems that institutions and communities face in today's rapidly changing world.

instituteforlearninginnovation.org

OUR SCHOOL DIVISION PARTNERS



nnschools.org

The mission of Newport News Public Schools is to provide quality education that encourages every student to realize his/her fullest potential.



spsk12.net

The mission of Suffolk Public Schools is to partner with the community, to provide an effective educational experience, and to prepare every student to find success in our complex society.



hampton.k12.va.us

The mission of Hampton City Schools, in collaboration with the community, is to ensure academic excellence for every child, every day, whatever it takes.

COMMUNITY PARTNERS



Virginia Seafood Agricultural Research and Extension Center



Our community partners worked with us to customize each and every STEM 360 experience to the specific learning needs of each school division and most importantly the students.

ABOUT OUR INSTITUTION



The Virginia Air & Space Center (VASC) is the official visitor center for NASA Langley Research Center. The Center is dedicated to preserving national achievements in air and space exploration, supporting NASA key messages and missions, and stimulating interest in the sciences. As a NASA visitor center, VASC connects students and teachers with NASA content and brings cutting-edge technology to the community, inspiring the next generation of scientists and explorers. The 110,000 square foot facility is home to the Apollo 12 Command Module, the P/A-1 Orion Test Vehicle, a collection spanning 100 years of flight with more than 30 historic aircraft, a hands-on space exploration gallery, unique space flight artifacts, and interactive exhibits that explore science, technology, engineering and math (STEM).

Over the years, VASC has evolved into the leading STEM science center in the Hampton Roads region. The Virginia Air & Space Center is a valued resource for the entire Hampton Roads community, which includes 1.4 million residents spanning from Williamsburg to Virginia Beach, Virginia. The center proudly works closely with the region's public and private schools.

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