Phase 2 Final Technical Report

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Executive Summary

Introduction

The STEM 360 project explores how utilization of an entire community's STEM (science, technology, engineering, and math) learning assets can be applied to improving upper elementary school student's STEM career awareness, academic achievement, STEM engagement and attitudes. Four strategies were used to enrich the existing STEM learning environment: In-school Educational Outreaches; Field Experiences to the Virginia Air and Space Center and other local informal STEM institutions; Family and Out-of-School Time Engagement through STEM Ambassadorship; and STEM Coach Engagement and Support.

This report presents data from Phase 2 of the STEM 360 project, an effort designed to refine and replicate the initial STEM 360 project. Unfortunately, because of the COVID-19 pandemic, Virginia public schools were closed in March 2020 resulting in students in the STEM 360 program being unable to participate in the spring 2020 activities, and thus not complete the full STEM 360 program, nor complete the year-end STEM 360 survey or Virginia State Standardized Testing. As a result, the project was unable to directly assess the impact of the three different levels of engagement on student outcomes in each of the four target areas. The project did administer a survey to participating teachers in Levels 1 and 2, in which they were asked to reflect on their own experience and their perceptions of how the STEM 360 program impacted their students' STEM (1) career awareness, (2) academic achievement, (3) engagement, and (4) attitudes. The highlights from that survey are presented below.

STEM Career Awareness

- The overwhelming majority of teachers agreed that overall, the STEM 360 program significantly impacted overall STEM career awareness for participating students. This was true for Level 1 and 2 teachers.
- Teachers felt that the experiences helped to broaden students' understanding of what a "STEM" career is and made them aware of careers that they might not have been familiar with previously.
- Teachers felt that learning about STEM careers was a key component of this program and some wanted even more information to support student STEM career awareness.

STEM Academic Achievement

- An overwhelming majority of teachers agreed that the program significantly impacted student's academic achievement. This was true for Level 1 and 2 teachers.
- Teachers felt that the STEM 360 program supported academic achievement since it increased student engagement, interest, and general curiosity about science.
- They also felt that the program supported and deepened their students 'understanding since they were able to make connections between these experiences and class material.

STEM Engagement

- Both Level 1 and Level 2 teachers were nearly unanimous in agreeing that the STEM 360 program impacted students' STEM engagement.
- Similar to the other student outcomes, teachers felt that the hands-on activities were very effective in supporting STEM engagement. Students found these activities fun and exciting such that it sparked their interest in wanting to know more.

STEM Attitudes

- A large majority of both Level 1 and Level 2 teachers agreed that the STEM 360 program impacted student attitudes towards STEM topics.

Introduction

There has long been a desire to more fully engage and encourage children and youth to pursue STEM related subjects and careers (NRC, 2012; National Science and Technology Council, 2018). However, there has been a growing awareness that school alone is insufficient to accomplish this societal goal (NRC, 2015; National Science and Technology Council, 2018). Increasingly, the science education field has been turning to more of a community-wide, "ecosystem" approach (e.g., Falk, et al., 2015; NRC, 2015). This approach acknowledges that to achieve a STEM literate and engaged society and workforce, no single institution can accomplish this alone (Traphagen & Traill, 2014). Rather, the entire STEM learning ecosystem of multiple community stakeholders, including schools, informal learning institutions, libraries, content experts, and families need to be involved (Barron et al., 2009; Bevan et al., 2010; Falk et al., 2016; NRC, 2015; Traphagen & Traill, 2014). And importantly, none of these resources can work in isolation; all must work synergistically within the context of a single, coordinated system (Falk et al., 2016).

The STEM 360 program is a unique collaborative initiative between the Virginia Air and Space Center (VASC), the Institute for Learning Innovation (ILI), and three Hampton Roads area school districts (Hampton, Newport, News, and Suffolk) that was designed to take exactly such an ecosystem approach to understanding and delivering STEM learning to 4th and 5th grade students. This immersive, multi-platform STEM (science, technology, engineering, and math) education engagement program and longitudinal research study (STEM 360) followed a cohort of students from 4th grade to the end of their 5th grade year. STEM 360 is specifically designed to influence the learning system of student participants to increase: 1) STEM work force awareness; 2) STEM academic achievement; 3) STEM engagement; and 4) positive attitude towards and recognition of the value of STEM (Falk & Griesmer, 2019).

As defined in detail in the Phase 1 STEM 360 Report (Falk, Palmquist, Meier, Griesmer & Price, 2019), the targeted strategies for STEM 360 program were based on an exhaustive literature review of key leverage points in the STEM learning ecosystem. In particular, STEM 360 has identified the following critical pieces of the STEM learning ecosystem: *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 (Norfolk Botanical Gardens, Virginia Aquarium, Virginia Zoo, and Topgolf); and *the designed learning experiences*—outreach programs within the school classroom, field experience, VASC STEM Saturdays, email communication with parents/ caregivers. This learning system is designed to provide participating students with opportunities to engage with STEM experiences throughout their day, week and year; experiences that are equal to or significantly enriched from common public education practice.

Program Overview

The STEM 360 project explored how different levels of STEM engagement influence youth STEM workforce awareness, STEM academic achievement, STEM engagement and STEM attitudes. Based on the literature, the aspects of the ecosystem that were used to enrich the existing STEM learning environment included: In-school Educational Outreaches; Field

Experience 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 1-hour programs conducted by VASC educators who had been identified as STEM Coaches. For example, one program provided students with the opportunity to learn about gravity, potential and kinetic energy, and friction by building a roller coaster. Another program used an owl pellet to explore food webs, food chains, producers, consumers, and decomposers.

Field Experience provided opportunities to engage students in more immersive STEM learning opportunities at places such as the Norfolk Botanical Gardens, the Virginia Aquarium and Marine Science Center, the Virginia Zoo, Topgolf, and the Virginia Air and Space Center. Students had the opportunity to learn about topics such as plant anatomy, ecosystems, and circuits. In addition, all field experiences were designed to emphasize STEM careers, including: Aerospace Engineering, Urban Planning, and Marine Biology.

STEM Ambassadorship was a family and out-of-school engagement opportunity where students were enrolled into the STEM 360 VASC Ambassador Program which allowed for free unlimited entry to VASC for each participating student in Levels 1 and 2. Monthly STEM Saturday programs were offered at VASC featuring a wide variety of STEM activities based around a theme. Guest speakers were often also featured. In Phase 1, the ambassadorship included the participating student and only one parent. In Phase 2, a change was made such that students could bring their families (up to five family members). This change was made in the hope of attendance improving at monthly STEM Saturday programs and other STEM opportunities.

STEM Coaches provided engagement and support for all participating schools in Levels 1 and 2. These VASC educators served as mentors to the students, conducted out-of and in-school education programs; attended and co-taught all field experiences with the students; greeted students and families at STEM Saturdays, and communicated with classroom teachers and parents about STEM opportunities in the community that might be of interest to students.

These four strategies were designed to be tested at three levels of engagement over the two-year program at three levels of intensity. Breaking the students into three groups was designed to help the project not only determine the overall efficacy of STEM 360, e.g., treatment vs. control, but also to test the relative cost-benefit of the two levels of treatment, e.g., whether the same benefits might accrue to students with even a minimal investment in out-of-school enrichment experiences. The three levels are described in Table 1.

Table 1. *Descriptions of treatment levels.*

Level	Intensity	Experiences
Level 1	Highest Intensity	Maximum amount of engagement with STEM learning opportunities. This level included: Four field experiences to informal learning organizations; four in-school programs; connection with a STEM Coach; family membership at VASC; encouragement to attend monthly STEM Saturday events at VASC.
Level 2	Intermediate Intensity	An enriched amount of engagement, but far less than Level 1. This level included: Two field experiences to informal learning organizations; two in-school programs, access to a responsive STEM Coach; membership at VASC for the duration of the study, encouragement to attend monthly STEM Saturday events at VASC.
Level 3	Control Group	This level was designed to provide a basis for comparison regarding pre and post program changes related to student's maturation or other Division-wide STEM interventions. The Level 3 experience included: One in-school program.

Research Questions

STEM 360 sought to address the following questions:

- How and in what ways could a comprehensive suite of learning interventions – both in- and out-of-school - measurably improve youth STEM career awareness, academic achievement, and STEM engagement and attitudes?
- How and in what ways did the results vary as a function of the level of learning intervention participants experienced?

Methodology

COVID-19 Pandemic

Due to the COVID-19 pandemic and the closure of Virginia public schools in March 2020, students in the STEM 360 program were not able to participate in the spring 2020 activities and therefore did not experience the full STEM 360 program. School cancelation also made it impossible for us to administer the year-end survey to students nor to collect Virginia State Standardized Testing scores. As a result, we were unable to directly assess the impact of the three different levels of engagement on student outcomes in each of the four target areas. Given this situation, we instead chose to administer a survey to participating teachers in Levels 1 and 2, in which they were asked to reflect on their own experience and their perceptions of their students' experiences in STEM 360. The questions on this survey were intended to address the key study research questions as well as provide some overall feedback about the program. Note that depending on when experiences were scheduled, some teachers may have participated in certain activities (prior to the school closure) whereas others might not have been able to.

Participants

Fifty-two teachers participated in Levels 1 and 2 of the STEM 360 experience. Among these teachers, 98% completed the survey. See Table 2 for a summary of teachers who completed the survey by division, school, and level.

Study Design

Educational interventions including in-school educational outreaches, field experiences, and STEM Saturdays were scheduled and delivered throughout the school year; designed to be as responsive as possible to the academic calendar and aligned with target science learning outcomes.

As stated above, students were randomly assigned by school, to either Level 1, Level 2 or Level 3. Tables 3a and 3b present a list of in-school educational outreaches, connected Virginia Standards of Learning (SOLs), and which Levels participated for years 1 and 2. Tables 4a and 4b provide information about the field experiences including the field location, topics covered, career connections students explored, and which Levels participated for years 1 and 2. Tables 5a and 5b present a list of STEM Saturdays during years 1 and 2.

Table 2. *Summary of teachers who completed the survey by division, school, and level.*

Division	School	Level	Teachers
Hampton	Andrews	1	4
	Booker	2	3
	Burbank	1	3
	Cooper	2	2[1]
	Forrest	2	3
	Langley	1	4
Newport News	Discovery STEM	1	3
	Dutrow	2	4
	Sanford	2	4
	Yates	1	4
Suffolk	Booker T	1	2
	Elephants Fork	1	3
	Hillpoint	2	7
	Mack Benn	2	6

Table 3a. *Year 1 in-school educational outreach program by level.*

Program	Science SOLs	Level 1	Level 2	Level 3
Earth, Moon, Sun	3.8;4.8	X		
Scream Machines	4.2	X		
Living Planet	3.5; 3.6; 3.9d-e; 3.10a; 4.5	X	X	
Electricity	4.3a-d, f	X	X	X

Table 3b. *Year 2 in-school educational outreach programs by level.*

[1] One teacher at Cooper did not complete the survey.

Program	Science SOLs	Level 1	Level 2	Level 3
Matter of Fact	5.4	X[2]		
Shake, Rattle, and Roll	5.6a; 5.7	X		
Gross Science	3.5; 3.10a; 4.4c; 4.5c	X[3]	X[4]	
Mad Scientist	3.1, 4.1, 5.1; Math 3.14, 4.10, 4.11, 4.12, 5.11	X	X	X

Table 4a. *Year 1 field experiences by level.*

Institution	Topics	Careers	Level 1	Level 2
Virginia Aquarium	Food Web vs. Food Chain, Adaptations, Habitats	Environmental Scientist, Ichthyology, Marine Biologist, Marine Mammologist, Marine Photographer, Microprocessor Designer, Ornithologist, Radio Technician, Satellite Systems Engineer	X	
VASC Spring	IMAX Film: Beautiful Planet, Planets, Orbits/Revolutions, Seasons/Tides, Moon Phases	Aerospace Engineer, Agronomist, Aircraft Mechanic, Astronaut, Astrophysicist, Excavator Operator, Farmer, Geologist, Life Support Technician, Satellite Technician, Telescope Operator, Welder, Wind Turbine Technician, X-Ray Technician	X	
Norfolk Botanical Garden	Plant Anatomy, Flower Dissection, Photosynthesis, Pollination	Anthropologist, Conservationist, Food Scientist, Forester, Historian, Horticultural Therapist, Landscape Designer/Architect, Landscaper, Medical Scientist, Natural Resource Manager, Turf Manager, Urban Planner, Wildlife Manager	X	X
VASC Fall	IMAX Film: America's Musical Journey, Fractions connected to music, Circuits, Insulators, Conductors	Astronaut, Electrician, Musician, Pilot	X	X

[2] Only 4 of 7 schools in Level 1 received this outreach program due to COVID-19.
[3] This outreach program was canceled for all Level 1 students due to COVID-19.
[4] Only 5 of 7 schools in Level 2 received this outreach program due to COVID-19.

Table 4b. *Year 2 field experiences by level.*

Institution	Topics	Careers	Level 1	Level 2
Topgolf	Science Investigation	Computer Engineer, Course Designer, Engineer, Inventor/Designer, Professional Golfer, Technician, Turf Manager	X	
VASC Spring	IMAX Film: Dream Big, Engineering Challenge, Egg Drop, Science Investigation	Astronauts, Engineers, Inventor, Scientist, Structural Engineer	X[5]	
Virginia Zoo	Food Web vs. Food Chain, Predator-Prey, Adaptations, Habitats	Animal Nutritionist/Dietician, Veterinarian, Zoo Habitat Designer (Architect), Zookeeper	X[6]	X[7]
VASC Fall	IMAX Film: Backyard Wilderness, Moon Colony, Building sustainable structures for survival, Stomp Rockets, Moon Characteristics, Apollo Mission Anniversary Celebration	Aerospace Engineer, Astronauts, Electrician, Farmer, Government, Life Support Technician, Power Plant Technician, Satellite Technician, Teachers, Technology Technician, Telescope Operator	X	X

Table 5a. *Year 1 STEM Saturday's themes, partners/activities, and the number of students and family members who attended.*

Date	Theme	Partners/Activities	# Students	# Family members
10/6/2018	A Date to Innovate	East Coast Polytechnic Institute (ECPI), 3D printed pumpkins, Camera Obscurer, Makey Makey, SMALLab, Maker Space	25	22
11/3/2018	Sports and Space	ECPI VA Sports Hall of Fame Impulse demonstration using a ball launcher, Trajectories in basketball, Archery Painting, Football helmet egg drop Challenge, Astronaut exercise relay, SMALLab	15	15
12/1/2018	Maker Space: Engineer It!	ECPI Analogue Lab and Studio Newport News Shipbuilding Catapults, Pin box camera/photo development in darkroom, 3D scanner, DIY Zoetrope, Makey Makey, Engineer Challenges, SMALLab	14	27
1/5/2019	Subzero Science	ECPI Circuits that function through temperature changes, Snowman Shooters, How snowflakes form, Dry ice comets, SMALLab	16	28
2/2/2019	Black History Celebration – Engineering	ECPI CHROME Paper airplane launchers, Build the highest tower (spaghetti/marshmallow challenge), Fly the most cargo (Paper airplanes), SMALLab, Learn how the heart works and create your own model heart in an activity that pays tribute to the medical industry pioneer Vivien Thomas, Create a constellation	11	12

[5] Only 4 of 7 schools in Level 1 received this field experience due to COVID-19
[6] Only 3 of 7 schools in Level 1 received this field experience due to COVID-19.
[7] Only 3 of 7 schools in Level 2 received this field experience due to COVID-19.

		telescope and map the sky just like cartographer, astronomer, almanac author, naturalist, abolitionist, and equal rights activist, Benjamin Banneker, Engineer your own Pulley. Alexander Miles – an African American Inventor, known for his work on the elevator		
3/2/2019	Women in STEM	ECPI Society of Women Engineers Catapults & Thermal Camera, Simulated X-Ray Photos, Candy DNA Chain - Rosalind Elsie Franklin was a chemist who brought to light the structures of DNA, Bridge that can hold 100 pennies, SMALLab	15	14
4/6/2019	What on Earth!	D'Art Center Recycled Art Installation, Water filtration, Rock cycle Activity, Rainbow refraction Activity, SMALLab	3	6
5/4/2019	International Space Day	NASA ECPI Cloud Activity, Straw Rockets, Stomp Rockets, Life of an Astronaut (exercise/nutrition), Make a Mars rover, Moon phase mobiles, Astronaut Dexterity Challenge, SMALLab	4	6
6/1/2019	Soar Into Summer!	Sunscreen Test, Alka seltzer rockets, Paper Flight Challenge, Mysteries of Flight, Sun prints, SMALLab	2	2

Table 5b. *Year 2 STEM Saturday's themes, partners/activities, and the number of students and family members who attended.*

Date	Theme	Partners/Activities	# Students	# Family members
10/5/2019	A Date to Innovate	Women in Aviation SMALLab, Maker Space, Binary Code Activity, Marble Maze	7	12
11/2/2019	Aviation Celebration	ECPI Armed Forces Communications and Electronics Association Straw Rockets, SMALLab, Paper Flight Challenge, Whirly Birds, Bernoulli's Principle Race, Plane Launchers	13	13
12/7/2019	Maker Space: Engineer It!	ECPI Catapults, Makey Makey, Engineer Challenges, Paper Bridges, Spaghetti Marshmallow Challenge, SMALLab	15	18
1/4/2020	Subzero Science	ECPI Which Substance melts ice, Snowman Challenge, Watercolor snowflakes, Penguin and Polar Bears- How do they stay warm?, Dry ice comets, SMALLab	10	11
2/1/2020	Black History Celebration – Engineering	ECPI Learn about design, fundamentals of flight, with the Tuskegee Airmen by designing a paper airplane that can carry as many coins as possible, Learn how the heart works and create your own model heart in an activity that pays tribute to the medical industry pioneer Vivien Thomas, Create a constellation telescope and map the sky just like cartographer, astronomer, almanac author, naturalist, abolitionist, and equal rights activist, Benjamin Banneker, Jump another Planet - Another Mae Jemison was the first black woman to travel in space, SMALLab	7	12
3/7/2020	Women in STEM	ECPI Marie Curie- X-Ray Pictures, Math tic-tac-toe - In honor of the West Area Computing Unit, made famous by the Hollywood movie "Hidden Figures", Create a double helix out of beads in celebration of Rosalind Franklin's contributions to the structure of DNA, SMALLab	2	2
4/4/2020	What on Earth!	Canceled due to COVID-19		
5/2/2020	International Space Day	Canceled due to COVID-19		
6/6/2020	Soar Into Summer!	Canceled due to COVID-19		

Findings[8]

Teachers reported that highlights of the STEM 360 program for students included both going on the varying field experiences as well as the outreach component of the program. Teachers also felt that students were very engaged in the hands-on aspects of STEM 360. Teachers mentioned that they enjoyed watching their students' excitement and that they were having fun while learning. One teacher said one highlight was,

> *Seeing the students enjoy themselves and they don't even know they are learning*.

Another reported:

> *I love this program! I love the field trips just like the kids, but the hands-on part of it all is priceless. I love seeing the kids' faces light up when they understand something more after they complete a STEM 360 activity or field trip. They love it.*

Teachers consistently stated that they found that the program positively impacted their students' learning. For example, teachers said that the program was effective in increasing student engagement, interest, and curiosity in STEM, particularly science. They also felt that it deepened student understanding since it built on material being covered in class. Some teachers mentioned that this program provided opportunities that they would not typically have. For example, students were able to visit local free-choice learning institutions such as the zoo. One teacher said:

> *The STEM 360 program had a huge impact on our students! It gave many students experiences they have never had such as visiting a museum, going to Top Golf, and touring the zoo! Watching them experience those trips for the first time was priceless! Students were excited about learning and were more interested in science and STEM. The program also had an impact on learning within the classroom, students were constantly making connections and developing a deeper understanding of topics we cover in 5th grade!*

Teachers also reported that the program had an impact on their teacher practice. They became aware or were reminded of the importance of hands-on experiences in learning, which gave them ideas for ways to integrate these types of activities into the classroom and connect the activities to the curriculum. They also started thinking about how to incorporate more STEM into their curriculum. For example, one teacher noted,

> *STEM 360 has made me prioritize science instruction and take time to make students aware of its connection to their everyday lives*.

STEM Career Awareness

The overwhelming majority of teachers (90%) agreed "a little" or "a lot" that overall, the STEM 360 program significantly impacted overall STEM career awareness of participating students. This was true for Level 1 and 2 teachers. They felt that the experiences helped to broaden students' understanding of what a "STEM" career is and made them aware of careers that they might not have been familiar, as observed by the following teacher:

[8] Since some teachers were not able to participate in all experiences due to the school closure, data related to particular experiences only reflects the perspective of those teachers who were able to participate.

At the end of every experience, there was discussion of the possible careers. In the beginning the facilitator was providing all the careers. But as the year went on, the students were making the connection themselves.

Among the in-school STEM 360 activities, of the teachers who participated in each of the activities, the ones that teachers viewed as most successful in supporting STEM career awareness included the Gross Science Outreach Ecosystems and Food Webs, owl pellet dissection (100%) and the pre-visit activities for VASC (Egg drop challenge 93% and Oreo moon phases 92%) and for the Virginia Zoo (92%). See Table 6. The field experiences that seemed most successful in supporting STEM career awareness were the trip to the Virginia Zoo (100%) and the SMALLab and engineer challenge at VASC (93%). See Table 7.

Teachers reported that they wanted even more information to support student STEM career awareness. Some ideas included having more opportunities to interact with STEM professionals such as scientists. Other ideas included having a STEM career day event and creating posters about careers to hang on classroom walls. Teachers felt that learning about STEM careers was a key component of this program as demonstrated in the following teacher quote:

I think that students need more exposure to the education that would be required to have a career in STEM - and that they could understand that college IS accessible to them no matter what their financial circumstances are right now.

Table 6. *Percentage of teachers who agreed a little or a lot that in-class experiences supported STEM career awareness by experience.*

	% agreed
Gross Science Outreach Ecosystems and Food Webs, owl pellet dissection	100
*Pre-visit Activity VASC Egg Drop STEM Challenge	93
Pre-Visit Activity Virginia Zoo Ecosystem Quest Game	92
Pre-visit Activity VASC Oreo Moon Phases	92
*Pre-visit Activity Topgolf Science Investigation Observations	91
*Matter of Fact Outreach States of Matter, Periodic Table, and the difference between elements, compounds, and mixtures	90
Mad Scientist Outreach Science Investigation and water displacement experiment	89
*Shake, Rattle, and Roll Outreach Tectonic plates and rock cycle activity	88

*Only Level 1 schools participated in these experiences.

Table 7. *Percentage of teachers who agreed a little or a lot that field experiences supported STEM career awareness by experience.*

	% agreed
Virginia Zoo	100
*VASC SMALLab and Engineer Challenge/Egg Drop	93
VASC Moon Colony & Stomp Rockets	91
*Topgolf	91

*Only Level 1 schools participated in these experiences.

An analysis of differences between Level 1 and Level 2 teachers failed to reveal any significant differences (X^2 (1) = .558, p = .455).

Academic Achievement

An overwhelming majority of teachers (90%) also agreed “a little” or “a lot” that the program significantly impacted student’s academic achievement. This was true for Level 1 and 2 teachers.

Teachers felt that the STEM 360 program supported academic achievement since it increased student engagement, interest, and general curiosity about science. It supported and deepened their students' understanding since they were able to make connections between these experiences and class material. They also felt that the hands-on activities were effective in supporting student academic achievement.

Among the in-school STEM 360 activities, of the teachers who participated in each of the activities the ones that teachers viewed as most successful in supporting academic achievement included the Shake, Rattle, and Roll Outreach Tectonic plates and rock cycle activity (100%) and the pre-visit activity for VASC - Oreo Moon Phases (96%). See Table 8. The field experience that, again, seemed most successful in supporting academic achievement was the trip to the Virginia Zoo (100%) (Table 9).

Table 8. *Percentage of teachers who agreed a little or a lot that in-class experiences supported academic achievement by experience.*

	% agreed
*Shake, Rattle, and Roll Outreach Tectonic plates and rock cycle activity	100
Pre-visit Activity VASC Oreo Moon Phases	96
*Pre-visit Activity VASC Egg Drop STEM Challenge	93
*Matter of Fact Outreach States of Matter, Periodic Table, and the difference between elements, compounds, and mixtures	93
Pre-Visit Activity Virginia Zoo Ecosystem Quest Game	93
Mad Scientist Outreach Science Investigation and water displacement experiment	92
Gross Science Outreach Ecosystems and Food Webs, owl pellet dissection	92
*Pre-visit Activity Topgolf Science Investigation Observations	91

*Only Level 1 schools participated in these experiences.

Table 9. *Percentage of teachers who agreed a little or a lot that field experiences supported academic achievement by experience.*

	% agreed
Virginia Zoo	100
VASC Moon Colony & Stomp Rockets	96
*VASC SMALLab and Engineer Challenge/Egg Drop	93
*Topgolf	91

*Only Level 1 schools participated in these experiences.

An analysis of differences between Level 1 and Level 2 teachers failed to reveal any significant differences (X^2 (1) = .558, p = .455).

STEM Engagement

Both Level 1 and Level 2 teachers were nearly unanimous in agreeing that the STEM 360 program impacted students' STEM engagement; all but one participating teacher (98%) agreed "a little" or "a lot" that STEM 360 enhanced student's engagement with STEM. Teachers felt that in-class experiences as well as field experiences were, overall, quite supportive (Tables 10 & 11). Similar to the other student outcomes, teachers felt that the hands-on activities were very effective in supporting STEM engagement. Students found these activities fun and exciting and

sparked their interest in wanting to know more. Few teachers mentioned experiences that could be improved to support STEM engagement.

Teachers expressed that the field experience to Topgolf was one of the experiences that was very successful. They specifically mentioned that this field experience supported student engagement by involving them in the scientific process.

> *The Topgolf experience was unlike something I had seen before. Students were having so much fun collecting data, they sometimes forgot to write it down. Then, once they tried again and wrote it, they realized it was okay to make mistakes and to keep testing their data. I walked around asking for examples of qualitative and quantitative data, and they shared several. They could recall the variables of the experiment, which was always a tough skill for 5th graders to differentiate. They enjoyed working together to make a conclusion and had lots to say when we returned to the school.*

Among the in-school STEM 360 activities, and of the teachers who participated in each of the activities, the ones that teachers viewed as most successful in supporting STEM engagement included the Pre-visit Activity VASC Oreo Moon Phases (100%) and the Matter of Fact Outreach States of Matter, Periodic Table, and the difference between elements, compounds, and mixtures (100%) (Table 10).

Table 10. *Percentage of teachers who agreed a little or a lot that in-class experiences supported STEM engagement by experience.*

	% agreed
Pre-visit Activity VASC Oreo Moon Phases	100
*Matter of Fact Outreach States of Matter, Periodic Table, and the difference between elements, compounds, and mixtures	100
Gross Science Outreach Ecosystems and Food Webs, owl pellet dissection	96
*Pre-visit Activity Topgolf Science Investigation Observations	95
*Shake, Rattle, and Roll Outreach Tectonic plates and rock cycle activity	94
*Pre-visit Activity VASC Egg Drop STEM Challenge	93
Mad Scientist Outreach Science Investigation and water displacement experiment	92
Pre-Visit Activity Virginia Zoo Ecosystem Quest Game	88

*Only Level 1 schools participated in these experiences.

Table 11. *Percentage of teachers who agreed a little or a lot that field experiences supported STEM engagement by experience.*

	% agreed
Virginia Zoo	100
VASC Moon Colony & Stomp Rockets	96
*Topgolf	96
*VASC SMALLab and Engineer Challenge/Egg Drop	94

*Only Level 1 schools participated in these experiences.

An analysis of differences between Level 1 and Level 2 teachers failed to reveal any significant differences (X^2 (1) = .809, p = .369).

STEM Attitudes

Similarly, a large majority of teachers (92%) agreed "a little" or "a lot" that the STEM 360 program impacted student attitudes towards STEM topics. As above, these positive impressions were true for both Level 1 and 2 teachers. Similar to how teachers talked about STEM engagement, teachers felt that STEM attitudes benefitted from the fun and exciting activities. Experiences that teachers pointed to were the field experiences to Topgolf and VASC, as well as in-class activities such as the egg drop experiment (100%), Matter of Fact Outreach States of Matter, Periodic Table, and the difference between elements, compounds, and mixtures (100%), the Oreo moon phase activity (96%), and the owl pellet dissection (96%). See Tables 12 and 13. Few teachers reported an activity that could be improved to support STEM attitudes. However, of those that did respond, teachers mainly mentioned wanting more of all of the experiences.

Table 12. *Percentage of teachers who agreed a little or a lot that in-class experiences supported STEM attitudes by experience.*

	% agreed
*Pre-visit Activity VASC Egg Drop STEM Challenge	100
*Matter of Fact Outreach States of Matter, Periodic Table, and the difference between elements, compounds, and mixtures	100
Pre-visit Activity VASC Oreo Moon Phases	96
Gross Science Outreach Ecosystems and Food Webs, owl pellet dissection	96
*Pre-visit Activity Topgolf Science Investigation Observations	95
Mad Scientist Outreach Science Investigation and water displacement experiment	92
*Shake, Rattle, and Roll Outreach Tectonic plates and rock cycle activity	86
Pre-Visit Activity Virginia Zoo Ecosystem Quest Game	85

*Only Level 1 schools participated in these experiences.

Table 13. *Percentage of teachers who agreed a little or a lot that field experiences supported STEM attitudes by experience.*

	% agreed
*VASC SMALLab and Engineer Challenge/Egg Drop	100
VASC Moon Colony & Stomp Rockets	96
*Topgolf	95
Virginia Zoo	95

*Only Level 1 schools participated in these experiences.

An analysis of differences between Level 1 and Level 2 teachers failed to reveal any significant differences (X^2 (1) = .058, p = .809).

STEM Coach

When asked about the STEM Coaches in the program, there was near-unanimity on the value of the STEM Coaches (98% of teachers agreed that Coaches significantly contributed to at least one outcome). Virtually all teachers agreed "a little" or "a lot" that the STEM Coaches played an important role overall in supporting each of the four target student outcomes (Table 14). Teachers noted that they were effective since they were enthusiastic and engaging, worked to build relationships with the students, were relatable and personal, and at the same time knowledgeable.

Table 14. Percentage of teachers who agreed a little or a lot that the STEM Coach supported varying student outcomes

Student Outcome	% agreed
STEM engagement	96
STEM attitudes	96
STEM knowledge	94
STEM career awareness	92

As above, an analysis of differences between Level 1 and Level 2 teachers failed to reveal any significant differences (X^2 (1) = .809, p = .369).

Teacher Feedback

Teachers did not report many challenges. Unsurprisingly, among those that did mention challenges, they mostly related to lack of time and scheduling difficulties. Some expressed that it was difficult to juggle the participation in STEM 360 with other instructional time. To manage these challenges, teachers referred a lot to support they received from the STEM Coaches and that the teachers had great communication with them. When asked what one thing they would change to improve the STEM 360 experience for students, teachers again mentioned wanting more time for the experiences. When asked what they would NOT change about the program, teachers typically referred to having field trip experiences. Some also wished to keep the pre-visit activities. And some said that they would not change anything in the program.

Discussion

While the intention was to compare student data longitudinally from the beginning to the end of this two year program; comparing outcomes for each of the four target areas of STEM learning as a function of "Level", i.e., Level 1 "intensive" vs. Level 2 "moderate" vs. Level 3 "minimal/control", due to the challenges created by the COVID-19 pandemic we were unable to collect valid data of this kind and thus unable to make these comparisons. Nevertheless, results from Phase 1 (cf., Falk, et al., 2019) and the first year of Phase 2 (cf., Siegel, Falk & Meier, 2019) strongly indicate that student participation in STEM 360 has a positive impact on youth STEM career awareness, STEM academic achievement, STEM engagement, and STEM attitudes.

Also summarized above is some of the teacher feedback about the program that we also collected as part of our end-of-year teacher survey. Although again, broadly positive, there were important comments and we intend to use this important feedback about how specific activities contributed to positive student outcomes as we revise and improve the STEM 360 program for the upcoming year.

While we were not able to collect student data at the end of this year, it is clear that both Level 1 and Level 2 teachers perceived the STEM 360 program to be an important and successful STEM enrichment effort; one that significantly improved the STEM career awareness, achievement, engagement and attitudes of their students. In fact, teachers in both Level 1 and Level 2 were so enthusiastic about the STEM 360 project that they created a ceiling effect that made it impossible for us to distinguish level-related differences in teachers' perceptions of the impact the STEM 360 project had on students. Although level-related effects were not evident from teacher

feedback, based on results from Phase 1 and the first year of Phase 2, we strongly believe that end of year testing would have almost certainly revealed level-related effects. None-the-less, as summarized above, it is clear that the teachers involved with STEM 360 at both Level 1 and Level 2 engagement were uniformly convinced that the STEM 360 program materially benefited their students and afforded students with unique opportunities that they would not have been otherwise able to experience.

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