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Blast-Building Leaders for Advancing Science and Technology: A Partnership Between the Virginia Space Grant Consortium and the University of Virginia, Virginia Polytechnic Institute, and Old Dominion University

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BLAST – BUILDING LEADERS FOR ADVANCING SCIENCE AND TECHNOLOGY: A PARTNERSHIP BETWEEN THE VIRGINIA SPACE GRANT CONSORTIUM AND THE UNIVERSITY OF VIRGINIA, VIRGINIA POLYTECHNIC INSTITUTE, AND OLD DOMINION UNIVERSITY

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Abstract

This paper presents the development and delivery of an educational STEM program that is designed to encourage and support rising ninth and tenth grade students' interests in the pursuit of STEM-related college degrees and careers. BLAST (Building Leaders for Advancing Science and Technology) is a three-day, summer, residential, on-campus, STEM learning experience. With the intention of improving the STEM-related workforce pipeline in the Commonwealth of Virginia, Virginia Space Grant Consortium (VSGC) offers multiple BLAST sessions across the Commonwealth. The BLAST program is designed as two full days of intensive three-hour lecture-lab experiences that are reinforced by fun-filled STEM-related evening events. VSGC, as part of NASA's Space Grant College and Fellowship program whose mission is to support STEM education, workforce development and research, has secured funding from the Commonwealth of Virginia to offer the BLAST program. BLAST annually targets approximately 240 students with 80 students per session (with higher numbers in some years) who have a C+ or better average, and who have limited previous STEM-related experience outside of the classroom. It is surmised that if more students are exposed to STEM-related experiences that they may be more likely to become interested in and motivated to one-day pursue a STEM-related discipline, thereby helping to alleviate the STEM-related workforce shortages in Virginia and the United States. BLAST is offered at three public universities in Virginia: The University of Virginia, Virginia Polytechnic Institute, and Old Dominion University. Faculty and graduate students at each of the respective universities design and implement a BLAST session that draws upon their respective faculty's strengths and interests. In this paper, a content analysis was conducted of BLAST directors' responses to interviews to identify common and unique strengths across the different BLAST sessions. Additionally, a preliminary content analysis of post BLAST participants' responses was conducted to discern participants' perceived impacts of their BLAST experiences. If the U.S. is to successfully increase its STEM-ready workforce, one solution is to increase the number of interested students in the pipeline by motivating and exposing them to greater STEM-related educational experiences.

Keywords: STEM education; Pre-college summer educational STEM-related programs; Engineering and Science Education.

1 INTRODUCTION

The National Aeronautics and Space Administration (NASA) is an independent agency of the United States federal government. It is responsible for supporting the civil space program, aeronautics research, and space exploration and research. NASA receives its funding from the annual federal budget which is passed by the United States Congress. In 1989, NASA initiated the National Space Grant College and Fellowship Project, known as Space Grant. The purpose of the Space Grant is to improve Americans' understanding of and participation in NASA's aeronautics and space projects. Based on a consortium of 52 agencies, one in each of the 50 states, with an additional agency in the District of Columbia and the Commonwealth of Puerto Rico, the NASA National Space Grant Program with its 1,209 affiliates including universities, colleges, industry, museums, science centers, offers fellowships, scholarships, and funding for STEM curriculum and faculty development. Many of the colleges and universities administer pre-college and public service education projects aimed at

enhancing science and engineering education, as well as support research and public outreach efforts. NASA is a key funding agency for the Virginia Space Grant Consortium which also receives funding from the Commonwealth of Virginia, as well as through competitive grants from other federal agencies and organizations. VSGC fosters participation in several immersive STEM programs at the eighth, ninth, tenth, eleventh and twelfth grade levels to further retain students in the pipeline for STEM studies and careers and continues that mentorship at the higher education level with scholarships, internships and student flight and design programs. Virginia Space Grant Consortium (VSGC) offers multiple summer BLAST sessions that annually enroll approximately 240 students across three participating universities: University of Virginia, Virginia Tech, and Old Dominion University. Since 2003, BLAST has served a total of 2,748 students. The purpose of this paper is to discuss Building Leaders for Advancing Science and Technology (BLAST), a pre-college STEM-related program managed by the Virginia Space Grant Consortium and to describe the common and unique strengths of the BLAST sessions offered across the Commonwealth.

1.1 Virginia Space Grant Consortium – The Role in BLAST Program Support

VSGC secured state funding in the amount of \$218,000 per year beginning in 2012. In 2022, the budget was increased by \$182,000 to a total of \$400,000 which will allow about 400 students to participate in BLAST programs at two additional universities, totaling five university sites beginning in summer 2023. The program is primarily funded by the Commonwealth of Virginia. The Virginia Space Grant Consortium through its base NASA funding supports the oversight role of the Consortium Director, accounting, and other managerial and educational functions related to BLAST.

Information about the BLAST program and application process is widely distributed to key faculty and administrators in public and private schools throughout Virginia and to other VSGC stakeholders who have contacts with the larger target audience. For example, school administrators who oversee STEM in their buildings, counselors, teachers of STEM and some CTE courses all receive information and a BLAST flyer via email for distribution, as well as suggested language to use when sharing the opportunity via school print and online newsletters and school social media sites. Interested students complete an application in which they are asked several open-ended questions about their interest and experiences with STEM; additionally, a teacher recommendation is required. BLAST receives many more applications each year than can be accommodated; for the 2022 year, there were nearly 1,100 applications for 240 openings. To select participants, each application is thoroughly reviewed by at least two external reviewers using a rubric to assess the quality of the students' applications and the teacher recommendation letters. Final participant selection is based on reviewer feedback and additional efforts are made to ensure that the participants represent a geographic and demographic diverse body of students, as well as students who may have limited access to STEM extracurriculars.

Similarly, BLAST chaperones must apply and be selected; the application requires two professional recommendations. BLAST chaperones must be teachers who are licensed in a relevant field to teach middle or high school in Virginia and must be currently employed in a public or private schools in Virginia. Chaperones are selected based on the quality of their application and their responses to open-ended questions about their interest in the position and in their experience facilitating similar events, as well as the quality of their recommendations. Chaperones receive room and board for the duration of BLAST as well as a \$1,000 stipend for the three days and nights of chaperoning the BLAST session. The BLAST program has been offered every year in person since 2013 with the exception of having to cancel the program due to the COVID pandemic in 2020. In 2021, a virtual version of BLAST was offered.

2 METHODOLOGY

An interview protocol was developed and used to conduct interviews with directors and administrators of BLAST programs at the University of Virginia, Virginia Polytechnic Institute, and Old Dominion University. A content analysis of the directors' responses to interview questions was conducted to determine common and unique strengths across the programs, which were later confirmed by the directors in writing.

Additionally, a preliminary content analysis was conducted of BLAST participants' responses to questions in post BLAST evaluations which were conducted by the Virginia Space Grant Consortium.

3 RESULTS

Analysis of the interviews conducted with BLAST directors at the three participating universities identified common and unique strengths among the BLAST programs which are shared below. .

3.1 Common Strengths Across the BLAST Programs

BLAST is designed as a summer, three-night, college dorm-living, residential, hands-on intensive STEM-learning experience for rising ninth and tenth graders across Virginia who have a C+ or better average, and who have had little prior STEM-related experience. Participants arrive on a Sunday afternoon for check-in and are assigned to one of eight groups of ten students each, are assigned a roommate, and are assigned a residential teacher-chaperone who oversees a group. Universities receive approximately \$45,000 from VSGC in support of their BLAST program; typically, each university offers one BLAST program per summer, should there be additional funding the universities may be asked to offer a second BLAST program on a rotational basis. BLAST directors may choose to raise additional funding for their respective BLAST programs. VSGC funding is used to pay for participant and chaperone rooms and board, as well as chaperone stipends; lab supplies and equipment; and faculty, graduate, and undergraduate student lunches, dinners, and stipends. Payment to faculty varies across the universities, i.e., two of the universities pay faculty a stipend, but faculty at the remaining university consider their involvement in BLAST as part of their service load. Regarding assessment of the BLAST programs, VSGC conducts a short pre and post assessment of changes in participants' STEM interests, as well as participants' perceptions about their BLAST experiences.

Virginia Space Grant Consortium (VSGC) offers multiple BLAST sessions to approximately 240 students annually across three participating universities: University of Virginia, Virginia Tech, and Old Dominion University; serving approximately 80 students at each university. Since 2013, BLAST has served a total of 2,747 students. All BLAST programs are designed similarly; as two full-days with two three-hour lecture-lab sessions (one before lunch and one after lunch) each day, for a total of four sessions. A BLAST program starts on Sunday evening with faculty introductions and an interactive activity conducted by either faculty or graduate and undergraduate student support staff. The three-hour lecture/lab sessions occur on Monday and Tuesday in which groups of twenty students each rotate across the four sessions. Evening sessions focus on an engineering- or science-related interactive event. Although the design of the BLAST programs is similar across the participating universities, the focus of the programs differs based on the universities and the interests of the faculty involved. In addition to faculty, participants have an opportunity to engage with graduate and undergraduate students who are STEM majors and to ask them questions about their university experiences in STEM. A brief description of each university's BLAST program follows.

3.2 Unique Strengths of the Various BLAST Programs

An analysis of the responses to questions asked during interview with the BLAST directors was conducted and verified and expounded on by the directors in writing.

3.3 University of Virginia (UVA) BLAST, Charlottesville, VA

UVA's BLAST program is a collaboration between the College of Arts and Sciences and the School of Engineering and Applied Sciences. From Mechanical and Aerospace Engineering, the Trash Sliders engineering teaching kit was adopted. The activity introduces participants to the engineering design process while introducing concepts of sustainability and upcycling [1]. Students learn about vehicle suspension systems by designing, building, testing, and retesting a vehicle they build to transport a liquid water payload over an obstacle course. After testing their vehicles, students compete to see which groups' vehicle spills the least water. The vehicles are constructed from "trash", e.g., plastic milk jugs, etc., to emphasize the value of reuse and upcycling.

From the Department of Biology, a "Pandemic!" activity is used to teach students basic principles of epidemiology, virology, and immunology through games, simulations, and case studies; the activity was developed in 2017, two years prior to the COVID-19 pandemic but modified in 2021-2022 to address real-time pandemic issues. Students solve an epidemiology puzzle through a Centers for Disease Control online activity, build a Foldscope microscope that they later take home, and model a SARS-CoV-2 viral infection, replication, and immune response using Origami Organelle models. Students also learn the mechanics and science behind a COVID-19 test by disassembling and exploring it.

The Department of Chemistry's graduate student outreach group, LEAD (Learning through Experiments and Demonstrations) has developed a forensic chemistry activity called "Poisoned Kool-Aid". Students determine which metallic salt contaminates a sample. Conducted in an undergraduate chemistry laboratory, students get to experience a college chemistry laboratory. The students learn basic lab techniques, e.g., spectrophotometry. They determine the identity of the contaminant through a comparison of known samples and determine the concentration by generating a standard curve. Students also get to practice using scientific notation, graphing, and graph interpretation.

Working with the FIRST Cavalier Robotics Team 619, the Mars Rover activity shows students how scientists and engineers work in teams and the importance of communications. Students build and launch a rover to Mars to solve a series of puzzles and challenges. The rover is built and controlled (over Bluetooth) using a Lego Mindstorms kit. After construction and testing, the rover is "launched" to a simulated Martian environment that is concealed from the students by a screen. Their only view of the Martian surface is from a lightweight drone camera mounted on their rover. At the start of the activity, team members are assigned roles and responsibilities, e.g., Principal Investigator, Mission Project Manager, Project Scientist, Payload Manager, Mission Operations Manager, etc. No one team member has all the information required to solve the challenge; students must cooperate, communicate, and work as a team to succeed. During the process, members of the Cavalier Robotics Team 619 mentor students in leadership, teamwork, and communication.

During the evening activities, students attend a physics demonstration show, a chemistry demonstration show, are visited by an astronaut, take a tour of the Aerospace Research Lab, and spend a special evening at the historic McCormick Observatory where they can view objects in the night sky through large powerful telescopes.

3.4 Virginia Polytechnic Institute (VT) BLAST, Blacksburg, VA

VT's BLAST program is housed in the College of Engineering. It aligns with NASA's interest in the development of engineers and scientists in support of its critical mission and its support of the aerospace industry. It is directed by a college administrator who is responsible for engineering outreach programs, one of which is BLAST. While the technical programming varies from year to year depending on faculty availability, there are some sessions that are always included, e.g., Game Changineer, Protein Electrophoresis, and Cybersecurity Capture the Flag; all which showcases VT's motto, Ut Prosim, That I May Serve.

The Game Changineer program is a fun and creative way to learn computational thinking, design and the logic behind popular games [2]. The platform allows users to create sophisticated video games and discover the critical thinking behind them. Participants learn programming concepts, such as logical reasoning, problem-solving, debugging, algorithmic design, and critical and computational thinking. While the skills needed to create programs such as Pacman or Space Invaders take years to learn, this platform allows students to create their own game in just a few hours. Artificial-intelligence (AI), together with natural-language processing (NLP) and compilation technology, are embedded within the system to automatically translate the English sentences into code and help the user debug any unclear sentences. In so doing, the learners practice "thinking like a computer scientist", while enjoying their own creation at the same time. Game Changineer is free and web-based, which allows participants to perfect their games even after BLAST ends.

The protein electrophoresis lab is part of Biotech-in-a-Box outreach. For more than 20 years, the Fralin Life Sciences Institute has made available complete kits for bringing biotechnology to Virginia high school and community college classrooms. Kits contain all the equipment needed for experiments, and the Institute pays round-trip shipping between Virginia Tech and schools. During BLAST, the students perform polyacrylamide gel electrophoresis (SDS-PAGE) of proteins and can design several types of experiments. For example, they can answer forensic questions, determining the identity of a seafood sample by comparing the proteins in the unknown sample to those of known species. In addition, the experiment can be used to demonstrate differences in protein expression in mammalian organs; for example, beef liver and beef muscle contain the same DNA, yet the proteins expressed in the two tissues are quite different because of their unique functions.

Capture the Flag (CTF) is a cybersecurity competition designed to challenge participants to solve computer security problems to earn points for their team. BLAST's CTF is a Jeopardy-style competition, with challenges across several categories with increasing point values as the problems get more difficult. The game has something for everyone; introductory challenges help inexperienced participants learn the basics. As challenges increase in difficulty, players acquire new skills and solve new kinds of

problems. More advanced players can continue to hone their skills by focusing on the hardest of challenges. The CTF includes categories such as cryptography, networking, web applications, reconnaissance, and reverse engineering. The program is hosted by the Virginia Cyber Range which provides scalable, cloud-hosted infrastructure for over 400 high schools and universities containing virtual environments for realistic, hands-on cybersecurity labs and exercises. A CIA representative also visits with each class to share potential careers and emphasizes the important role that cybersecurity plays in our national defense.

3.5 Old Dominion University (ODU) BLAST, Norfolk, VA

Initially, ODU BLAST was housed in the College of Education and Professional Studies. The program had a climate science focus that supported NASA's role as a global leader in the study of Earth's changing climate. The topic of climate change and sea-level rise is of great importance to ODU because Norfolk is identified by the U.S. Army Corps of Engineers as a city second only to New Orleans, LA in terms of its vulnerability to sea-level rise; Norfolk is ranked 10th among the world's most important port cities whose assets are at risk [3]. Given that the topic of climate change cuts across many academic disciplines and research interests, faculty and students from every college were involved.

Topics addressed during the three-hour lecture/lab sections included: the albedo effect (reflection) and its contribution to sea-ice melt; water harmonics and its impact on dispersion and erosion; robots and their use in cleaning up contaminated sites due to flooding; building more sustainably in an effort to mitigate and adapt to climate change and sea-level rise. Evening sessions included: impacts on the economy due to supply chain and transportation disruptions; increases in respiratory illnesses due to increases in droughts and fires; increases in mosquito borne diseases due to flooding; and the need to communicate climate change and offer community-based preparedness/training programs more effectively. Faculty from mathematics education worked with BLAST faculty in both the day- and evening sessions to ensure that the M (math) in STEM was addressed in the context of the topic being presented.

Our Home Our Planet was a simple low-cost experiment conducted by the Department of Physics in which the basic physics of climate change was demonstrated. Students simulated the greenhouse effect by adding two tablets of Alka-Seltzer to a bottle of water in which CO₂ was released; no tablets were added to another bottle. Both bottles were placed close to a desk lamp with a 75-watt light bulb. During the subsequent 30-40 minutes in which other climate-related experiments were conducted, participants recorded in three-minute intervals the temperature of the air in both bottles. At the conclusion of the experiment, students measured, plotted, and calculated percentages and differences between the bottles' temperatures. The air in the bottle with the extra CO₂ from the Alka-Seltzer tablets became several degrees warmer [4].

In Water Water Everywhere, conducted by the Department of Civil Engineering, participants learned about the use of green infrastructure in the management of flooding and improving water quality. The main purpose of this activity was to demonstrate the impact of bioretention cells, an engineering solution frequently used to alleviate flooding caused by storm water run-off and projected sea level rise. Participants built and tested the performance of various materials used to build bioretention cells, e.g., topsoil, sand, pea gravel, mulch, and geotextile a material that enhances infiltration. Students experimented with different levels and configurations of materials and measured and plotted the differences in water quality and levels of run-off to determine which configuration of materials worked best. [5].

Currently, ODU's BLAST is housed in the Batten College of Engineering & Technology. While it is more engineering and engineering-technology focused than it was initially, it still includes the sciences and industrial technology. Today, ODU BLAST aligns with NASA's interest in the development of engineers and scientists in support of its critical mission and the aerospace industry. It focuses on NASA's mission to EXPLORE EARTH by enhancing our understanding of Earth's atmosphere and climate through scientific research driven by new instruments and data. ODU's BLAST program is directed by the Chair of Engineering Technology who is involved in various engineering outreach programs of which BLAST is one.

Given the team orientation of the program, multiple icebreaking and team building exercises are conducted. Engineering related topics include fluid mechanics, structural design, additive manufacturing, cybersecurity; modeling and simulation, environmental engineering, instrumentation technologies, and the internet of things (IoT); science-related topics include earth science/planetarium demonstrations, physics, and bio-inspired robots. During one of the special events, one of the deans from either the College of Science or the College of Engineering & Engineering Technology visits with the participants. In another evening event, a faculty member who is an Arctic explorer provides a riveting power-point presentation that illustrates the conditions under s/he works. Afterward, a male and female

participant are invited to race each other as they try to put on the cumbersome subzero clothes and perform simple tasks; it gave a whole new meaning to “chill-laxing” [6].

4 CONTENT ANALYSIS OF PARTICIPANTS’ RESPONSES TO POST BLAST EVALUTIONS

Based on a content analysis of students’ response to questions asked during the post BLAST evaluation of all BLAST sessions across the three participating universities, common themes emerge. Students overwhelmingly report that their interest in STEM increased as a function of their attending a BLAST program, especially after having been exposed to so many exciting STEM-related topics, e.g., space exploration, physics, material science, aerospace engineering, biomedical engineering, mechanical engineering, robots, coding, chemistry, cyber security, environmental science, etc. Several students also mentioned that after BLAST, they would consider majoring in engineering in college. It was also interesting to note student comments on how being with other STEM-interested students made it easier for them speak up and contribute to discussion because they felt more comfortable and confident when being around other like-minded students. Some students commented on being surprised at how creative they were in their approaches to problem solving when presented with challenges. Students also commented on how fun it was to learn the engineering design, test, and retest process and the importance of collecting data as they attempted to improve their designs through multiple design iterations. It also was interesting to read that many of the students enjoyed seeing the application of math in the solutions they devised during the challenges which were posed during the various STEM-related sessions and evening activities. Several students commented on having learned that working together in a team can lead to better solutions than when working alone; that there was strength in collaboration, even though it required more communication among the team members. Some students commented on how exciting it was to learn about the different career options and that it will be difficult for them to identify which STEM field to pursue in college and as a career. Students also commented on having made friends in BLAST; it was observed that many shared contact information when they departed.

5 CONCLUSIONS

The feedback received from BLAST participants, parents, Chaperones, and others involved in the program is overwhelmingly positive every year. Across all sessions, students very clearly express that the breadth and depth of the BLAST program experience impacts their attitudes about STEM courses, their next steps in education, and the careers they intend to explore further. For some, this meant a change of course as they learned that they enjoyed an experience in a new field more than something with which they were already familiar. Many students affirmed their passion for engineering but said that the BLAST program helped them to focus on a field more narrowly, e.g., mechanical or chemical engineering. Students and parents also mentioned that by spending time on an actual campus and interacting with college faculty and students, they realized that they may need to improve their academic efforts significantly to be on track for their academic and career goals; in essence, BLAST inspired them to think more seriously about what it takes and what it means to be a STEM major. Perhaps just as important as these academic changes were the personal connections students made with each other. Friendships were forged that extended well beyond the end of the BLAST program and by extending their support network to include friends with similar interests, VSGC staff, and on-site BLAST faculty, BLAST participants were motivated to remain engaged with VSGC programs and to pursue additional STEM opportunities that will keep them in the STEM career pipeline. Up to 25% of BLAST participants go on to participate in other VSGC STEM-related programs and perhaps go on to pursue STEM degrees and careers that will help to alleviate the STEM-related workforce shortages in Virginia and the United States.

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