STEM Enhancement in Earth Science (SEES): A reimagining of an onsite NASA/TSGC/UTCSR high school internship program

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Abstract

NASA, the Texas Space Grant Consortium, and The University of Texas at Austin Center for Space Research support the STEM Enhancement in Earth Science (SEES) program which provides selected high school students with exposure to Earth and space research. Interns learn how to interpret NASA satellite data, conduct mission design, and explore planetary research while working with scientists and engineers in their chosen area of work. This project addresses the national need to increase the number of high school students, particularly under-represented minorities, and those from under-served areas that will pursue STEM college degrees and the value of conducting authentic research for high school students. However, during these unprecedented times, NASA Texas Space Grant Consortium and The University of Texas Center for Space Research had to reimagine our summer internships and youth collaborative programs to develop virtual and socially distant educational plans due to the COVID-19 effects to "reimagine quality education opportunities for a changing world."

1. Introduction

Education departments from in-classroom and out-of-classroom settings have been forced to move to virtual programming. As the country faced unprecedented times, we strategically investigated virtual and safe in-person options that properly served our students and families. NASA Texas Space Grant and its partners, dedicated to providing stellar opportunities for youth of all ages, have reimagined how these programs can engage audiences, even at a distance.

NASA Texas Space Grant implemented a nationally competitive high school internship program where students conduct authentic research while being mentored by NASA subject matter experts. The internship, usually hosted on the University of Texas campus, moved to a virtual platform with the unexpected result of including hundreds of additional students. Students identified mosquito larvae that carry Zika and West Nile Virtus, used NASA data to address issues from COVID-19, analyzed ice melt in Greenland with data from NASA satellites, and designed lunar and Mars outposts, all while increasing their knowledge about NASA Earth Science, Python coding, and NASA missions and opportunities. New tools, computer programs, and apps provided experiential opportunities for participants to conduct their investigations in a virtual environment with valid scientific results.

Texas Space Grant took an existing successful onsite program and reimagined it in a virtual environment. In depth preparation by program staff and mentors incurred challenges and successes. We will explore how the integrity of the program and mission was achieved while still keeping participants safe. As museums, science centers, and youth programs adjust to the current health crisis, we must be mindful that programs and opportunities may not return to the way they were, expecting guests to always come to us in-person and in large crowds. Our goal is to address ideas and methods used to create programming that is relevant now and, in the future, as we all reimagine STEM education.

Significant changes that occurred when the program went virtual include: additional projects were added to include more students, increase in the number of interns due to no travel or in-person expense; increase in contact hours with their NASA subject matter expert, Speaker Series added on NASA missions and opportunities, and a virtual student showcase broadcasted as a two-day event. Based on evaluation results, items that were missed due to the virtual event include: opportunity to engage face-to-face with NASA experts, opportunity to experience college life, tour of a NASA facility to experience and see first-hand research by NASA scientists, engineers, and astronauts, and the opportunity to experience long-term research with like-minded students.

Interns are selected on the basis of their academic records, written application that includes responses to essay questions and video about their interest in STEM. Traditional projects provide housing, meals, and local transportation for those selected. A limited number of travel scholarships for flights to Austin are available for those in need. To accommodate students with summer jobs or other commitments, several virtual projects will also be offered. Application information may be found here: http://www.tsgc.utexas.edu/sees-internship/

2. Lesson Plans

This project directly addresses NASA's education mission goal to *attract and retain students in STEM disciplines. SEES:*

1) *utilizes NASA resources that align with the Framework for K-12 Science Education,*
2) *engages high school students and teachers in authentic mission-based research, and*
3) *enables NASA scientists and engineers to engage more effectively and efficiently with learners of all ages through mentorship opportunities.*

2.1 Objectives of the SEES program:

- Increase the number of students enrolling in STEM majors in college and pursuing STEM careers, with an emphasis on underserved populations
- Increase interactions among science experts, NASA researchers, secondary school teachers, and high school students through summer internships and web-based activities.
- Increase the knowledge of students about Earth's history, Earth system science, laser altimetry, and NASA technologies for studying Earth through summer internships.
- Increase the number of students using NASA Earth Observing data and NASA Earth system models to investigate and analyze our changing Earth through new web-based interface and activities from summer internships to include classroom differentiation.
- Provide opportunities for participants to understand and be a part of NASA's role in climate investigations and how these studies fit into the global picture.

2.2 Project Overview:

For the original on-site SEES program, fifty interns were carefully chosen on the basis of their academic records, written application, recommendation letter, and video highlighting their interest in STEM. Each selected intern was placed into a team with a scientist mentor. They completed 60 hours of distance learning activities that must be accomplished prior to the residential internship. The two-week residential internship is where interns must be on-site at The University of Texas Center for Space Research. The internship included daytime research activities, experiential learning activities, evening STEM activities, and field investigation. The residential internship gives students the opportunity to experience college life by living in a dorm, participating in activities, and eating in the cafeteria. Each year, several teachers and graduate students are selected as chaperones for the SEES program and support activities and are with the interns during the time they are on campus. The primary focus of the internship is for the students to learn how to interpret NASA data while working with scientists and engineers in their chosen area of work in the hopes that these students will major in STEM when they go to college.

The project team, made up of NASA SME's, NASA-trained science teachers, college professors, NASA scientists, astronomer, engineers, and graduate students, identified NASA curriculum and activities to actively engage students in on-line learning prior to the start of the internship. Due to the pandemic, all projects transitioned to virtual in 2020. Students completed approximately 90 hours of remote instruction on NASA Earth and Space Science, Computer Coding, and Project Specific background to prepare them for the internship. Students working in traditional projects such as: Astronomy, Aerospace Engineering, Emergency Response, Ice Cloud and Land Elevation Satellite (ICESat), Lunar Exploration, Mars Settlement Design, Mars 2020, and Gravity Recovery and Climate Experiment (GRACE) worked in small groups of 4-8.

A total of 90 hours of instruction prepares the student for the internship. 30 hours of instruction on NASA earth science content including NASA Eyes, Orbital Mechanics, Space Race, Remote Sensing, My NASA Data, GRACE, ICESat, Cryosphere, Science on a Sphere, EM Spectrum, Chasing Pluto, Kepler, and Astrobiology, 30 hours for three-levels of Python coding, and an additional 30 hours of subject-matter content to prepare students for their individual projects.

Faced with the pandemic and the opportunity for students to utilize NASA data as mitigation strategies, we added four strands of COVID research. Modules were: Food Supply, Increased Health and Safety, Space Exploration for a Better World, and Sustainable World – Sustainable Future. We expanded the Mosquito Mapper internship content and engagement resulting in 7000 field observations and 8000 land cover images analyzed.

2.3 Projects and their descriptions:

Astronomy

In the astronomy project, students learn about the scale of the Universe as well as have a chance to contribute to astronomy research through NASA Citizen Science projects. Interns work on the Galaxy Zoo galaxy classification, finding clumps and tracing spiral arms projects. During the course of the internship, students help astronomers process the vast amount of available data while discovering galaxy types. Interns make conclusions about the frequency of different object types and learn about star formation and galaxy evolution through their own research.

Using Satellites for Emergency Preparedness

Interns focus on a recent flood, wildfire, or tropical storm events, review satellite image datasets from NASA, the European Space Agency (ESA), and the US Geological Survey (USGS) collected before, during and after the event, and test best practices for rapid mapping of information extraction derived from these data. They use image analysis and investigate related geospatial information resources with the goal of creating and distributing products for emergency response applications and societal benefit. Past projects have utilized geospatial applications including QGIS, Google Earth Engine, and MultiSpec as well as Python and JavaScript for coding.

Weighing Where the Water Goes

Interns analyze data from GRACE (Gravity Recovery and Climate Experiment), twin satellites launched in March 2002, that are making detailed measurements of Earth's gravity field changes and revolutionizing investigations about Earth's water resources over land, ice, and oceans, as well as earthquakes and crustal deformations. These discoveries are having far-reaching benefits to society and the world's population.

Measuring Environmental Changes with Altimetry

Interns examine altimetry products and parameters over a wide range of global surfaces (e.g. ice sheets, sea ice, vegetation, ocean) from two Earth observing laser altimeters; The Ice, Cloud and Land Elevation Satellite (ICESat), operational from 2003-2009 and ICESat-2, which launched in 2018. In addition, the interns investigate other Earth observing satellite datasets and observations for furthering scientific discovery. The analyses include data visualization and validation using independent resources and complementary measurements to explore how the comprehensive observations can inform investigations associated with Earth's dynamic processes most influencing our environment and climate.

Aerospace Engineering Project

The Aerospace Engineering team designs a satellite and mission to monitor one or more aspects of the Earth's environment. The team chooses environmental aspects to be monitored, define the satellite's orbit, identify the sensors that are carried on the satellite, specify the satellite's launch site, and the choose rocket to be used for the launch. Preliminary work includes having each team member: 1) Choose, learn about, and summarize information about a current Earth-orbiting environment monitoring satellite, 2) Identify, research, and propose an environmental phenomenon to be monitored by the satellite to be designed by the team, 3) Research one or more sensors to be used to monitor the phenomenon identified in item 2, and 4) Document and share the information by creating a video, present the video, and answer questions from viewers outside of our team.

Mars Exploration

Prior to sending humans to Mars, we need an infrastructure on the planet surface that is necessary to sustain the first crews when they arrive. This includes power, habitation, water, food, health maintenance, mobility (space suits and rovers), emergency care, and scientific support functions. Using basic engineering design principles, interns design a Mars village that will allow people to live and work productively and safely for up to 1000 days on the Mars surface. Small scale prototypes will be built by 3D printing.

Mars 2020

Interns design a project around the four key goals of Studying Mars' Habitability, Seeking Signs of Past Microbial Life, Collecting and Caching Samples, and Preparing for Future Human Missions. With these same goals, the Mars2020 mission will pave the way for future human expeditions. Mars2020's Perseverance rover will also test a method for producing oxygen from the Martian atmosphere, identify potential In Situ Resource Utilization Targets (such as subsurface water), improve landing techniques, and characterize weather, dust, and other environmental conditions that could affect the sustainability of future astronauts living and working on Mars.

Exploration and Habitation of the Moon

Interns form a team that is responsible for the design of a lunar habitat that is capable of sustaining a long-term human presence on the Moon. Success in this endeavor required many areas of expertise, and each intern took on one of a variety of engineering or science roles that make up one cohesive design team. Through gaining knowledge of the most pressing and current scientific questions about the Moon, the team finds the most appropriate landing site that would not only provide the best opportunity to conduct science, but also one that provided the valuable in-situ resources that will be needed for sustained human habitation on the lunar surface. The design phase of the lunar habitat allows for a vast amount of creativity and provides a unique view of how the disciplines of science, engineering, biology, physics, and chemistry are all needed for the success of any mission involving humans.

GLOBE Observer Earth System Explorers

The GLOBE Observer Earth System Explorers virtual internship option connects interns with the exciting science of applying NASA Earth Observations to the global health threat of mosquito vector borne diseases. The virtual format of the GLOBE Observer Earth System Explorers enables interns to conduct their internship from their home. Participants will gain experience in field research, remote sensing, computer science and data analysis, while contributing to the scientific understanding of mosquito ecology, human health, and land cover classification. Interns access and analyze data using online tools such as the GLOBE Advanced Data Access Tool, Collect Earth Online, AppEARS, NASA Worldview, Climate Engine, Google Earth Engine and ArcGIS Online. Data products and research outcomes resulting from the GLOBE Observer Earth System Explorers team will be the basis of a co-authored peer reviewed research paper.

COVID19 Strands:

Interns explore mitigating the effects of COVID 19 on staple industries. Using NASA data, students construct a product around the four focus areas: Increased Safety and Health, Grocery Shortage, Sustainable Future, and Space Exploration. The product is designed for one of the four focus areas with respects to the effects of the COVID 19 virus on the topic addressed. Team projects engage participants in 120—150 hours of focus specific research, working closely with NASA SME mentors. The commitment is spread over 8 weeks and the final product culminates in a conceptual design of the chosen product, document work by creating a video presentation, present the video, and answer questions from viewers outside of the team.

2.4 Program Modifications:

With the onset of the COVID 19 Virus, the shutdown of many facilities including NASA centers and universities as a response to the COVID 19 restrictions created a dilemma for the future of the 2020 program. The best course of action needed to be identified to transition to a virtual experience while still maintaining the integrity of what makes the SEES internship unique. Transitioning to a virtual environment created a rare opportunity to expand our reach to many more exceptional U.S. students from around the world. In response, the program was reorganized and reimagined to create a full virtual SEES internship experience for the top 50% of student applicants. The 60 original students from previous years grew to a total of 333 high school sophomores and juniors from 45 US states, 1 territory, and 2 from oversees.

Once confirmation was received, we placed the original 60 students into projects based on their top 3 choices of the original project strands. The other 273 were placed into the 4 new COVID strands and the GLOBE Mosquito Mapper project. The original projects worked with Scientists and Engineers conducting NASA supported research on various topics like galaxy classification and remote sensing. Our COVID strands were focused on possible solutions to how COVID might affect certain areas of industry like space, food supply, food shortages, health, and safety.

In previous years, pre-internship activities would begin with 60-90 remote work hours prior to coming to the university with limited mentor contact. Mentors would hold one introductory meeting in a virtual environment, but any interaction with the students aside from that meeting was limited to email questions regarding the remote work. However, in the 2020 SEES Virtual Internship environment, the project mentors worked through a remote classroom with the interns to support and complete the work as a team. The students were able to complete the pre-internship lessons working alongside their mentors to prepare them with the tools they needed to navigate through the virtual internship. Interns worked remotely with NASA SME through Skype, Google classroom, Base Camp, and Zoom. This method not only allowed us to expand our reach but was advantageous to both the students and the NASA SME.

One pre-internship component was reorganized for the virtual setting. A differentiated Python course that varied in difficulty was offered. The course taught the basics of Python programming language covering lists, controls, string manipulation and more. The course was migrated to Basecamp software platform to create an all-in-one toolkit for the interns to working remotely. Mentors and undergraduate volunteers offered their Python expertise to answer questions and verify coding projects. Over 300 students completed the Python certification course, with 79 working through all three levels to complete the advance certification.

Throughout the previous on-site mentorships, interns enjoyed lecture discussions on a variety of Earth and space science topics from experts in the field. To mimic the on-site lecture discussions, students participated in a Virtual Speaker Series where they were able to interact with subject matter experts in a wide range of topics related to their projects in astronomy, Mars 2020, COVID, and more. During the speaker presentations, there was a cumulative total of over 1,100 attendees over the 11 subject matter expert presentations. Students were guided in career and degree discovery as well as their exploration of:

- How is COVID affecting major industries and the media?
- How do we separate space fact from fiction?
- What are the directives for NASA’s Human Exploration Missions?
- How are meteorite samples curated and classified?
- What is NASA’s Moon to Mars mission?
- How do meteors provide clues to Earth’s past?
- What are basic star formations and how are they formed?

The internship concluded with student research teams presenting their projects to an audience of UT scientists and engineers, as well as other interns and their guests via a live Zoom webinar and Q&A. Over the course of two days, 82 team projects presented to a live audience. Student projects were prerecorded with students “in the wings” ready to answer the live questions being asked by the audience and their peers. The webinars were a huge success with over 3000 views in the last few months with a duration of three hours.

The live public event was broadcast as a two-day event on YouTube, 2020 SEES Virtual Showcase, with presentations by selected research teams from each project. The 2020 presentations were broadcast for a national audience and can be viewed here:

https://www.youtube.com/watch?v=pjAhHMU3e74&t=650s
https://www.youtube.com/watch?v=Yhn5nuYMDH4&t=8121s

3. Lessons Learned:

3.1 Evaluation Methodology

Four methods were used to provide annual evaluation of progress toward attaining the anticipated outcomes of SEES Virtual Internship.

1. SEES records were independently reviewed to verify the percentages of underrepresented students including minority students and females who applied for the program, were selected, and who participated in virtual program. The analysis provided an assessment of progress toward the desired outcome to increase the number of underserved populations pursuing careers in STEM related fields.
2. Interviews with the program's mentors were conducted to obtain feedback of participation and outcomes of the virtual internship to identify specific project activities that contributed to the outcomes and will influence modifications in programming for next year.
3. All SEES participants were surveyed –interns, teachers, graduate students, and mentors – for their evaluation of the program. Descriptive statistics and criterion references were applied to the survey items with categorial response options and a six-step method of thematic analysis was applied to narrative responses to open-end survey items.
4. Outcome mapping was used to obtain success stories to evaluate outcomes of the influence of the virtual summer internships on the students selected. For 5 years, students will be contacted and monitored annually to provide individually in their own words a brief summary of (a) Student's Accomplishments/Awards (b) Student's Internships (c) impact TSGC support had on student in their career or future goals. This approach will provide a powerful thematic description of outcomes and enables a quantitative estimate of the overall success of the virtual internship.

Progress inspection showed the majority (60%) of survey respondents were female. This proportion compares very favorably to the program's target of more than 20% females. The proportion of female interns appeared to increase across the years.

More than one-fourth (29%) of the survey respondents described themselves as Hispanic or Black or American Indian/Alaska Native (i.e., members of racial ethnic minority populations underrepresented in science and engineering education). This proportion is substantially short of the program's stated target of 65% Hispanic or African American.

Regarding specific areas of STEM knowledge and skills, more than half indicated their experience in the SEES experience contributed to "very much" to their development in specific domains of STEM knowledge and skills indicative of scientific literacy tabulated this year. In a follow-on survey of interns by the external evaluator, regarding specific areas of STEM knowledge and skills, more than half indicated their experience in the SEES program contributed "very much" to their understanding of scientific process, their knowledge of earth processes, and other aspects of their knowledge, skills, and personal development.

In a comparison of student evaluations when SEES was conducted on-site to the virtual program, we found: students wanted the face-to-face experience, students did not experience the college life of living in the dormitory, lack of opportunity to visit NASA Johnson Space Center and visit laboratories, scientists, and engineers was a disappointment to many and often a once-in-a-lifetime opportunity that was missed, students lacked the opportunity to work in collaborative groups to utilize the 3D print lab, robotics tools, and field investigations.

3.2 Student Assessment

The students provide honest feedback about the program and themselves.

The best aspect of the SEES is quotes include:

- *"Having experienced mentors with decades of STEM and NASA experience who genuinely took interest in our team of students…The opportunity to do real world research, experience working as a team under great mentorship"*
- *"…working with a team of like-minded people who cared about the material and learning…feel that I have a much greater understanding of scientific process and good connections to my mentors and teammates"*
- *"I was able to work with bright peers from around the nation, learn from talented mentors and guest speakers, and gain real-life experience in the world of STEM"*
- *[SEES] "changed my world by introducing me to a whole new realm of scientific skills, concepts, and resources that NASA researchers use to study the universe…opened my eyes into the world of possibilities in future careers in Earth & Space Science"*
- *"Having this insight into NASA has helped me understand what a future in this field could look like…taught me a lot and connected me with so many scientists that are passionate about what they do"*
- *The diversity – "The best aspect of the SEES internship was getting to meet and work with people from all over the US"*
- *Learning to work in virtual connected environment – "I think the best aspect of my SEES experience was learning how to work on challenging material virtually and learning how to collaborate in difficult situations"*

Part of SEES that you would change quotes include:

- *"I would change the one thing SEES could not change, to be in person instead of virtual. I think the interns could not bond the same way as the former interns on the speaker panel bonded in their experiences. However, if the only alternative was to cancel the internship, I am so grateful [they] worked so hard to create virtual internship"*
- *"I wish that I was able to attend the in-person internship instead of online, but given the circumstances this experience was still stellar"*
- *"I think we all improved out virtual communication skills greatly by the last couple of weeks, but getting to know each other before our project even got started could have been beneficial for our team in the future"*
- *"I would have liked to have more time to connect with other students in different groups…maybe a zoom call with break-out sessions to meet each other"*
- *"more self-guided work and…more about other NASA missions" "more time to individual project work" "make it longer!" "longer introduction so we could have similar starting points in terms of coding" "having longer presentations times would be nice" "I love SEES as it is, but maybe allow future SEES interns to rotate through each research topic"*
- *"Overall, the SEES program was just perfect with the amount of mentor aid and presentations"*
- *"I really enjoyed the internship and cannot think of anything I was dissatisfied with or found to be a hindrance"*
- *"I would not change a single thing. I had an amazing time"*

3.2 Areas of Concern

When moving to an all-virtual internship we encountered:

- Technical issues

- Distractions and time management of students
- Keeping students motivated in virtual environment
- Understanding course expectations
- Lack of in-person interaction and engagement
- Scheduling conflicts
- Students attending multiple virtual programs

3.3 Broad assessment

Broadly, the SEES program has provided insight into the state of STEM:

- More students would like to participate in the SEES program than can be accommodated.
- Students would love spending time doing more STEM experiences.
- Students enthusiastically excel in as much STEM material as we can provide whether in person or virtually.
- The virtual program emphasis should be on team building STEM activities within the focus teams to foster relationships.
- Allow students to explore topics individually and as a team.
- Allow students to guide their own research and they will flourish.
- Allow students to have more individual project work

4. Evidence of Impacts

Before the program, most students…

- Had a limited knowledge of what NASA does and the variety of STEM fields employed
- Did not consider a NASA career, but now they are excited about STEM careers and looking forward to more internships
- Had limited access to summer internships due to COVID19

High school interns' feedback about ways in which the SEES experience affected their career plans was obtained with a multiple-choice item. Intern responses in descending order of frequency were:

- SEES experience reinforced or increased interest in pursuing a STEM career that was already in my plan (77%). This group included males and females, more than half of the 12 students who were Black or Hispanic, and all students from rural schools.
- Already planning to enter a career in STEM and SEES experience did not affect the plan (12%)
- SEES experience opened my eyes to a career I had not formerly considered (11%). This group included females and males, fewer than 5 of the 12 students from minority populations that are under-represented in science and engineering education, and none of the students from rural schools.
- Zero of the students indicated the SEES experience had made them less certain that STEM is what they want to do.

In each year of the SEES internship program, all interns that responded to the end-of-internship survey reported they expect to obtain higher education (Bachelor's degree or higher) and nearly all indicated firm intention to pursue a career in STEM. This result compares favorably to the program target of 90%.

5. Program results

Year-end evaluation results show that SEES is on track to achieving its stated objectives for:

- Increased number of students, particularly underrepresented and underserved who will major in STEM in college and/or become employed in STEM careers.

- Impact of SEES on student interns
- Increased knowledge and science literacy; and
- Increasing interactions among science experts, NASA researchers and SME's, secondary school teachers, and high school students.

TSGC tracks student progress after completion of the program. From the first 5 years of data: 98% begin college in a STEM discipline.

A video assessment was assembled by a former intern about the SEES program: https://youtu.be/w_qkyaTK6FM

Where are the former student interns now?

Follow-on evaluation results show that 95% of SEES participants are in college majoring in a STEM degree. Examples include: Aerospace Engineering, Astrophysics, Physics, Mechanical Engineering, Computer Science, Mathematical and Computational Science, and Biomedical Engineering just to name a few. Students are attending universities such as Yale University, Rice University, MIT, Columbia university, University of Texas, Stanford University, California Polytechnic State University, Vanderbilt University, and University of Colorado Boulder.

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Fig. 1 Pre-COVID SEES intern trip to NASA Johnson Space Center with visits to mission control rooms, the neutral buoyancy lab (NBL), Astromaterials Research and Exploration Science (AMES) building, robot labs, and Saturn V.

Fig. 2 Pre-COVID Astronomy team crafts telescopes

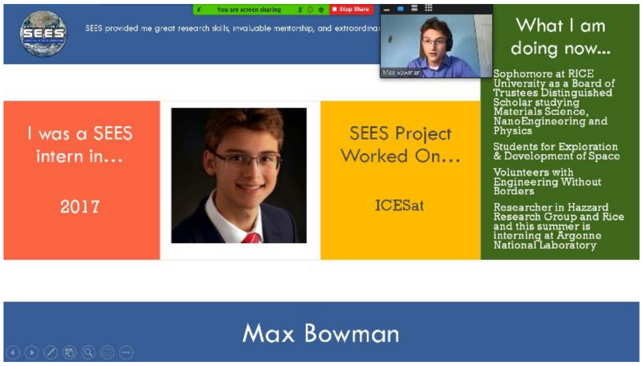

Fig. 3 Post-COVID SEES Alumni return to share how being a SEES intern has impacted their college and career journey.

Fig. 4 Post-COVID Emergency Response Team presents their Disaster Response Research using MAGIC that lead to the creation of an emergency response application during the 2020 SEES Virtual Showcase.