STEM Enhancement in Earth Science (SEES): A NASA/TSGC/UTCSR High School Internship Program

(Active, Experiential, and Collaborative Learning)

Timothy Urban, Margaret Baguio

Texas Space Grant Consortium, Center for Space Research, The University of Texas at Austin
3925 West Braker Lane, Suite 200, Austin, TX 78759, USA
E-mail: urban@tsgc.utexas.edu

Abstract

NASA, the Texas Space Grant Consortium (TSGC), and The University of Texas at Austin Center for Space Research (CSR) 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 while working with scientists and engineers in their chosen topic area. 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.

1. Introduction

Through a partnership of institutions and organizations that support STEM education, the Summer Intern Program effort began in 2010 as a three-year cooperative Education/Public Outreach (EPO) extension of several CSR NASA ROSES awards (Research Opportunities in Space and Earth Science). Subsequent years were made possible through a combination of NASA's GRACE mission outreach funding and TSGC support. Evolution of the program continued in 2015 with a new NASA award that elevated the newly named SEES program to a national audience.

2. Background

The original program began in 2010 with an education grant designed to leverage a set of NASA projects at CSR, using NASA's Earth observing satellites as a catalyst for the implementation of a six-week high school student internship program to support STEM education. The initial target audience was all rising sophomores, juniors, and seniors within Central Texas (as housing was not provided until 2016). The applicant pool grew annually through word-of-mouth of the positive experiences, and soon the applications were received geographically from throughout Texas and several out-of-state applications. In 2013, the program was reduced to four weeks, which allowed more students to apply to participate. In 2015 we chose to focus the program on sophomores and juniors (rising juniors and seniors) in order to maximize impact on STEM college major choices; 75 applications were received. With SEES going national in 2016 and 2017, the number of applications has also grown substantially, with the current level of reviewing of 500-600 applications making a significant portion of pre-internship work. At every step, our candidates exceeded the targeted advertisement; the past two years we have had applications from many students (U.S. citizens) living in other countries.

Most significant changes occurred with the growth of the program going national: more projects were identified for more teams (4 in 2010 to 8 in 2017), and therefore more interns could be accepted (11 in 2010 to 42 in 2017); the first two weeks of the SEES program are now online with students working remotely with their scientist mentors; the program includes funding for housing interns at a dorm on the UT campus for the two weeks onsite.

Interns are selected on the basis of their academic records, written application that includes written essay questions, letter of recommendation, and video about their interest in STEM. The potential program impact on students is also considered. Housing, meals, and local transportation are provided for those selected. Travel scholarships are available to any student in need. Application information may be found here: http://www.tsgc.utexas.edu/sees-internship/

Each selected intern is placed into a team with a scientist mentor. They receive a SEES "box" with 60 hours of distance learning activities that must be completed prior to the residential internship. The residential internship is for two weeks where interns must be on-site at The University of Texas Center for Space Research. The internship includes daytime research activities, experiential learning activities, evening STEM activities, and field investigation. 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.

3. Rationale

3.1 National STEM need

Well-documented trends have been reported nationally of declining interest, poor preparedness, a lack of diverse representation, and low persistence of U.S. students in Science, Technology, Engineering and Mathematics (STEM) disciplines. This project addresses the national need to increase the number of high school students, particularly under-represented minorities and

those from underserved areas that will pursue STEM college degrees.

Statistics on the state of education in the United States indicate a decreasing trend in domestic students choosing to major in and successfully completing degrees in Science, Technology, Engineering and Mathematics (STEM) disciplines [1]. Leaders in STEM fields have recently called for major initiatives to be undertaken nationally to address these educational trends [2,3,4].

In engineering, the need for change has been highlighted by American Society for Engineering Education's (ASEE) Engineering Deans Council and the Corporate Roundtable (1994); the National Research Council (1995); the National Academy of Engineering (2002 and following); and the National Science Foundation. In a Forbes Leadership Forum article by Rodney C. Adkins, senior vice president of IBM, Adkins stated, "*When I graduated from college, about 40% of the world's scientists and engineers resided in the U.S. Today that number has shrunk to about 15%."* To turn this trend around, we seek to to improve both the size and composition of the STEM pipeline. Adkins continued, "*We need to improve the composition of the STEM education pipeline to influence more women and underrepresented minorities. Although women fill close to half of all jobs in the U.S., they hold less than 25% of STEM-related jobs. At the same time, 43% of school-age children today are of African-American, Latino, or Native American descent.*"

3.2 SEES assets

The SEES program 1) utilizes NASA facilities and assets to provide work experience, research, and educational opportunities for high school students to encourage STEM careers and preparation; 2) provides opportunities for students and teachers to participate in experiential learning activities that will connect learners to NASA-unique resources in Earth and space sciences; and 3) prepares STEM educators and leaders to deliver quality STEM instruction utilizing NASA assets and content.

By leveraging the strengths of this partnership, SEES is:

- Educating students by utilizing rigorous STEM curriculum enhancement activities that meet national science, technology, engineering, and math standards and encompass the research and technology of NASA's Earth Science mission directorate.
- Providing secondary students with authentic NASA mission-based opportunities that build STEM knowledge, skills, and career awareness through a nationally competitive High School Summer Intern program that challenges students to conduct research from data supplied by Earth Science missions while being mentored by a project scientist.
- Providing opportunities for high school students to jump start their future and explore the possibilities of a STEM-related major or career while experiencing an on-site university setting.
- Expanding mentorship opportunities for university graduate students and Earth Science scientists as they engage students and teachers by incorporating research and data analysis.
- Inspiring a more diverse student population to pursue careers in STEM-related fields following involvement in NASA programs.

The project directly addresses NASA's education mission goal to "*Attract and retain students in science, technology, engineering and mathematics, or STEM disciplines".* In addition, it is contributing to: "*enabling STEM education*" through mentorship, selection of existing NASA content supporting STEM and the opportunity for high school students and teachers to conduct authentic NASA mission-based research, "*improve U.S. scientific literacy"* by integrating identified lessons and data for citizen scientists in repositories such as My NASA Data; "*advance national education goals"* by utilizing NASA resources that align with the Framework for K-12 Science Education; and "*leveraging efforts through partnerships"* by drawing upon the strengths of the collaborators who are part of this project. Each component further contributes to NASA's desired outcome of "*enabling NASA scientists and engineers to engage more effectively and efficiently with learners of all ages"*. The primary audience is K-12 Formal Education, with the primary focus on high school students and their teachers.

4. Program

4.1 Objectives

The SEES program has five primary objectives:

- Increase the knowledge of students and teachers about Earth's climate system and history, environmental changes, and NASA technologies for studying Earths
- Promote pursuing STEM careers.
- Increase interactions among science experts, NASA researchers and SME's, secondary school teachers, and high school students.
- Increase the number of teachers and 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.

4.2 Project Plans

The primary focus of the internship is for the students to learn how to interpret NASA satellite and mission data while working with scientists and engineers in their chosen area of work. Projects and their descriptions that were offered in 2017 include:

- *Aerospace Engineering* – This project will advance high quality STEM education by using NASA's unique capabilities. Exploration is a key driver in learning and innovation. Interns will immerse themselves in content and activities while learning about Earth-Moon Trajectories, Rockets, Lunar topography, observing Earth from the Moon, and designing a satellite payload. While tackling this engineering project, interns learn about the Earth Moon System Dynamics, Power Systems, and Communication while designing the mission.
- *Astronomy* – In addition to learning about the tools

astronomers use, interns will learn about the Solar System, its small bodies, and the hazards these bodies pose to Earth. They will search for unmeasured asteroids on archive images taken at McDonald Observatory, determine and report their positions. Interns will measure brightness variation for some of these bodies to find the rotation period and make conclusions about their shape. In the process they will be introduced to the digital image toolkit of astronomers.

- *Explore the Moon* – Interns will study the spectral effects of space weathering and impact gardening on the evolution of the lunar soil using remote sensing data. Understanding the effects from these processes improves the ability to map the true composition of planetary crusts. Interns will select and design a feasibility study on lunar mining.
- *GRACE (Gravity Recovery and Climate Experiment)* – Interns will analyze data from GRACE, 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.
- *ICESat (Ice, Cloud and Land Elevation Satellite)* – Interns examine ICESat mission data (2003-2009) and simulated ICESat-2 data (2018 launch). The satellites' laser altimetry is collected globally over ice sheets, sea ice, land, vegetation, and ocean/water surfaces. Analyses will include data visualization, satellite calibration, and comparisons with airborne laser data and other measurements. Investigations of primary questions surrounding the missions include how to link the data from the two missions and how to optimally compute changes of the Greenland and Antarctica ice sheets.
- *Mars Exploration* – NASA isn't just planning on eventually sending astronauts to Mars, it is hoping to one day actually build a colony on the red planet. What are the requirements? What resources are needed? Interns will design a Mars village that will allow people to live and work at distances much farther away from our home planet.
- *MAGIC (Mid-American Geospatial Information Center) Emergency Preparedness)* – Interns focus on a recent flood, wildfire, or tropical storm event, 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 information extraction from these data. We use image analysis and investigate related geospatial information resources with the goal of creating and distributing produces for emergency response applications and societal benefit.
- *MAGIC (Mid-American Geospatial Information Center) Flood Response* – Interns will compare National Weather Service Quantitative Precipitation Estimation (QPE) products derived from Radar with rainfall gauge values collected in the same time and space. This project provides ground truth evidence of estimations compared to captured rain totals. Interns develop Python scripts to automate the transformation of QPE point data to automate the transformation of QPE point data into an interpolated gridded surface that can be tiled for rapid consumption by web-based mapping applications via rest endpoints. Activities will simulate recent flood events with the goal of improving future flood response scenarios.

In 2017 we had our first "remote" NASA SME working with a team of students through Skype and Zoom. In this way we can connect students coordinated locally by a graduate student with a scientist or engineer working at a NASA center. This method was beneficial to both the students and the NASA SME and will be expanded in 2018.

The interns enjoy discussions with resident experts in aerospace engineering and Earth systems. Students are guided in their exploration of:

- How is the global Earth system changing?
- What causes these changes in the Earth system?
- How will the Earth system change in the future?
- How can Earth system science provide societal benefit?

Additionally, the interns experience team-building STEM activities, practice basic programming, enjoy lecture discussions on a variety of Earth and space science topics from experts in the field, and have field investigations which have included an iFLY STEM experience, the Challenge Center in San Antonio, the McDonald Observatory in Fort Davis, Canyon Lake Gorge, Freeman Ranch in San Marcos, and the NASA Johnson Space Center in Houston.

The internship concludes with team presentations in the CSR auditorium to an audience of UT scientists and engineers, university students, other interns, and guests. The 2016 and 2017 presentations were broadcast for a national audience and are stored here: https://www.youtube.com/channel/UCHoAiBx9Q73ifvETruxn3dA

4.3 Lessons Learned

4.3.1 Evaluation Methodology

Four methods are used to provide independent annual evaluation of progress toward achieving the expected outcomes of SEES.

1. Project records are reviewed to document the relative proportions of underrepresented students including minority students and females who apply for the program, who participate in online-course, and who are selected for the internship. This analysis provides evaluation of progress toward the desired outcome of inspiring a more diverse student population to pursue careers in STEM related fields.
2. Results mapping methods will be used to obtain success stories as hard data to evaluate outcomes of the summer internships. At the close of each summer session, the mentors and graduate students who supervise the internship projects will be asked to provide individually in their own words a brief description of participation and outcomes for (a) the one high school student

he or she judges had the highest level of success, (b) the one high school student he or she judges experienced the least amount of success in the internship program, and then (c) draw a line that represents the approximate distance between the "most" and "least" successful and (d) mark the place of all of the other interns on that line. This approach provides rich thematic description of outcomes and also enables quantitative estimate of overall success of the internship.

3. Interviews with the program's principal investigators will be conducted to obtain feedback on results of evaluation methods 1 and 2 in order to identify specific project activities that contributed to the outcomes and influenced adjustments in programming for each subsequent year.
4. Additionally, all SEES participants are surveyed – interns, teachers, graduate students, and scientists – for their evaluation of the program.

Regarding specific areas of STEM knowledge and skills, more than half indicated their experience in the SEES program contributed "very much" to their content knowledge of Earth science, inquiry/investigation-oriented learning strategies, authentic research and technology related problem-solving, understanding of scientific process, and knowledge of Earth processes. Regarding their general skills and personal development, more than half of the students indicated their experience in the SEES program contributed "very much" to their thinking critically and analytically, analyzing numerical and statistical information, acquiring job- or work-related knowledge and skills, working effectively with others, understanding people of other backgrounds, solving complex real-world problems.

4.3.2 Broad assessment

Programmatically, the SEES program has provided a wealth of insight into the state of STEM:

- Many more students want the opportunity than the program can accommodate
- Students eagerly absorb as much STEM material as we can provide
- A program emphasis should be on team-building activities
- Field investigations can be program highlights
- Let students jump right in to the research and they will flourish.

4.3.3 Evidence of Impacts

Before each program year, self-reflection from the majority of student participants showed:

- Most had a limited knowledge of what NASA does and the variety of STEM fields employed.
- The majority thought NASA was all about human exploration or studying other planetary bodies and did not know about NASA's Earth science fleet, but now they do and are excited about the missions.
- Few had considered a NASA career, but now they will.
- Most had considered a STEM field/major, and now more consider an area linked to NASA, Earth and space sciences.

From the data from the initial program phase (ROSES): 98% of interns begin college in a STEM discipline. Since SEES was implemented in 2016, 100% are pursuing STEM degrees when they enter college. TSGC will track the SEES students for graduation rate, major, and future education and careers placement.

4.3.4 Student Assessment

The students provide honest feedback about the program and themselves. Quotes include:

- *Earth science is a lot of hard work, and fun.*
- [Learning] *how to process large amounts of data quickly is a challenge.*
- [I learned] *how to program and how to use Matlab* [or Excel or GMT Generic Mapping Tools, etc.]
- *Stuff will go wrong*
- *You need to have good writing skills in order to persuade people to fund your ideas*
- *I have always known I would have a STEM career, but now I realize there are vast amounts of space/Earth fields of study that I had not considered before…such as movement of ice on our planet, detection of exoplanets, or Mars exploration.*
- *The best aspect was opportunity to work with researching faculty. I learned a variety of skills relating to scientific inquiry and research and in doing so realized a whole new career-path that I hadn't considered before.*
- *How often do high school students get to do real research with actual people who have doctorates in all kinds of engineering? UT/CSR was definitely one of the greatest and eye-opening summer experiences because I never thought I would be privy to satellite technology and missions and learn so much about how these satellite missions tell us so much about our environment and the world we live in. So much data is gathered from these satellites and I was ignorant of the actual importance of space research until I was selected for the program. The summer program definitely had an impact on my selected field of study. I was unsure about engineering but then after doing this program and learning about its requirement for analysis, deeper trains of thought, and creativity, I am motivated to pursue engineering.*

A video assessment was assembled by a former intern about the 2017 program: https://youtu.be/w_qkyaTK6FM

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

- Increasing students' knowledge;
- Promoting students' pursuit of STEM careers; and
- Increasing interactions among science experts, NASA researchers and SME's, secondary school teachers, and high school students.

Where are the former student interns now? Follow-on evaluation results show that 100% of SEES participants are in college majoring in a STEM degree. Examples include: Aerospace Engineering, Mechanical Engineering, Computer Science, and Biomedical Engineering just to name a few. Students are attending universities such as MIT, University of Texas, California Polytechnic State University, and University of Colorado Boulder.

5. Acknowledgement

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[1] Science and Engineering Indicators, National Science Board. Washington, DC, http://www.nsf.gov/statistics/seind06/ (2006)

[2] Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, The National Academies Press. Washington, DC (2007)

[3] A National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System, National Science Board. Washington, DC (2007) http://www.nsf.gov/nsb/edu_com/draft_stem_report.pdf

[4] America's Pressing Challenge – Building a Stronger Foundation: A Companion to Science and Engineering Indicators 2006, National Science Board. Washington, DC http://www.nsf.gov/statistics/nsb0602/nsb0602.pdf (2006)

Fig. 1 A SEES intern highlight is a trip to NASA Johnson Space Center with visits to the new and historic mission control rooms, the neutral buoyancy lab (NBL), Astromaterials Research and Exploration Science (AMES) building, robot labs, Saturn V and more.

Fig. 2 iFLY STEM experience

Fig. 3 Astronomy team crafts telescopes

Fig. 4 Students tracking simulated hurricanes with the Challenger Center