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Inspiring STEM Engagement: Space Science Education in the 21st Century

GERALD KNEZEK
Department of Learning Technologies
University of North Texas, USA
gknezek@gmail.com

RHONDA CHRISTENSEN
Institute for the Integration of Technology into Teaching and Learning
University of North Texas, USA
rhonda.christensen@gmail.com

CAROLYN Y. NG
NASA's Goddard Space Flight Center, USA
ADNET Systems, Inc., USA
carolyn.y.ng@nasa.gov

Space science education is an area of emerging importance in the 21st Century. Missions sponsored by the U.S. National Aeronautics and Space Administration (NASA) and programs facilitated through the NASA Space Science Education Consortium (NSSEC) offer unique opportunities to foster learner interest in space science as well as the broader field of science, technology, engineering, and mathematics (STEM). This introduction provides context for the major roles NASA plays in space science education and includes an overview for each of the articles in this issue.

Keywords: space science education, National Aeronautics and Space Administration (NASA), Space Science Education Consortium (NSSEC)

Introduction

This special issue focuses on space science education, an area of emerging importance as a new generation of scientists is needed to extend the work begun by those responsible for sending the first missions outside the confinements of Earth's gravity. The U.S. National Aeronautics and Space Administration (NASA) Science Mission Directorate (SMD) delivers compelling, high impact science programs to the public while inspiring the next generation of explorers (NASA, 2020a). With missions studying Earth, Moon, Mars, the solar system and beyond, NASA promotes collaboration across and between disciplines. These missions provide great opportunities to engage and educate the next generation of science and engineering leaders. In 2015, numerous educational projects in support of SMD science education objectives were integrated into the NASA Space Science Education Consortium (NSSEC) to bring NASA research and technology for heliophysics, astrophysics, and planetary science to learners of all ages throughout the country. The six articles featured in this issue describe projects and activities facilitated via the avenue of the consortium. This introduction to the special issue describes the context within which NASA promotes educational activities and provides brief overviews of the six featured articles.

A Need for STEM Experts at NASA

Fifty years ago, the Apollo program first explored the surface of worlds beyond our own. More recently, the Parker Solar Probe, the fastest human-made object, is flying toward the Sun to study our star. Going to the source of space weather will protect NASA assets both in space and on Earth. The soon-to-be-launched James Webb Space Telescope will study the first galaxies that were formed in the early universe, and possibly find habitable worlds around other stars. As NASA plans to land the first woman and the next man on the Moon (NASA 2020b), and eventually go on to Mars, scientists have been testing and building tools our future explorers may use on these journeys. From studying Earth to exploring the universe, NASA's work requires a diverse range of STEM skills. It is likely that young talents who will be needed to fill these needs were born since 2000 and are in our schools now.

What is NASA Doing to Encourage Space Scientists for the Future?

To prepare future NASA scientists and engineers, NASA envisions a systemic exploration approach for learning about topics that inspire, engage, educate and eventually employ students impacted by the activities (NASA, 2020c). NASA and NASA-funded education specialists have translated unique science discoveries into stimulating and informative activities in Science, Technology, Engineering and Mathematics (STEM) for learners of all ages. Through a broad and diverse set of programs, projects, activities and products, youth may experience the science and the adventure of NASA's scientific explorations of our home planet, the solar system, and the universe beyond. As outlined in the Federal Strategy for STEM Education and Engagement (White House, 2018), these activities help meet two goals: to increase STEM and computational literacy and to prepare the STEM workforce for the future. New science and new discoveries also inspire young talents to develop 21st century skills in communication, collaboration and innovation, which are all essential skills for the success of NASA missions.

Selected Outcomes from the NASA Space Science Education Consortium

The articles featured in this issue provide examples of the types of activities conducted by the more than 20 members of the NASA Space Science Education Consortium (NSSEC) and NASA eClips™. In *The STEAM Innovation Laboratory: Beyond the Makerspace Paradigm*, Cline and colleagues introduce the Science, Technology, Engineering, Arts, and Mathematics (STEAM) Innovation Laboratory (SIL) located at NASA's Goddard Space Flight Center in Greenbelt, Maryland. SIL uses a makerspace approach to bring NASA's universe of knowledge into educational spaces to increase scientific literacy and interest in STEAM careers. Through a series of stations specializing in virtual reality, electronics, mobile sensors and 3-D fabrication, the NASA team has succeeded in impacting over 82,000 educators and students, along with 1.6 million social media participants. An impact analysis revealed that participants gain a lasting knowledge of STEAM content from these hands-on activities.

In *A Retrospective Analysis of the Impact of SpaceMath@NASA on Student Performance in Math and Science*, Odenwald and colleagues analyze how real world, mathematics-based educational activities provide context for and break down barriers to learning in mathematics and science. SpaceMath@NASA provides teachers with real-world math activities in a

space-focused context in support of standards, by using current NASA discoveries as a starting point for motivating students to develop and use mathematics skills. The reach and efficacy of SpaceMath in supporting NASA's STEM mission was examined through an analysis of the resources and website data, a survey of a subset of listserv members, data from workshop attendees who were new users of SpaceMath, and a comparison group study. SpaceMath has been used by millions of educators who consistently report that SpaceMath aligns with what they teach, that they can immediately apply what they have learned in workshops, and are able to use it in their classes. Educators report that students enjoy the application problems and topics, are productively engaged, and ask questions that demonstrate curiosity and interest. The overall conclusion of the authors is that the use of SpaceMath to teach science concepts and apply math skills provides a context that enhances student understanding.

In *Space Public Outreach Team: Successful STEM Engagement on Complex Technical Topics*, Des Jardins and colleagues make the case that it is the responsibility of today's scientists, engineers, and educators to inspire and encourage our youth into technical careers that benefit our society. However, this responsibility is often buried beneath daily job demands and the routines of teaching. Space Public Outreach Team (SPOT) programs leverage a train-the-trainer model to empower college students to make meaningful impacts in their local communities by engaging and inspiring younger students through science presentations. SPOT takes advantage of the excitement of space and the natural way college students can serve as role models for children. Beginning with the original Montana SPOT program, authors present analyses demonstrating the success of SPOT, give overviews of program adaptations in West Virginia, and describe how college student presenters are able to share complex topics.

In *The Effects of a Museum of Science Fiction Event on Participant Knowledge and Interest*, Viggiano and colleagues show how the informal learning environment of the Museum of Science Fiction's *Escape Velocity* event offers an integration of science and science fiction in a variety of activities, talks, events, exhibits, and panels to further attendees' interest. Over the past four years during which Escape Velocity was held, participation increased each year from 2,700 attendees in 2016 to 5,300 attendees in 2019. This study examined the efficacy of this event as a learning experience through a survey of attendees. Attendees reported increasing their knowledge of STEM, being able to join many STEM activities, feeling empowered to connect with NASA scientists and resources, intention to look for ways to find out more, and wanting to learn more about NASA science.

Those who attended NASA-related panels reported statistically significant gains in knowledge and interest as a result of attending panels on Habitable Worlds, Apollo 50th Anniversary, and Space Weather.

NASA eClips™ Interactive Lessons: A Three-year Study of the Impact of NASA Educational Products on Student Science Literacy is a paper that includes an empirical research study comparing two different methods of teaching space science concepts to students in grades 4 through 8. Within the eClips program, NASA Spotlite has been researching the impact of students developing and using short videos to understand and address science misconceptions. Based on data from 100 students, the researchers concluded that implementing these video-based lessons to confront misconceptions resulted in improved student achievement and that the use of web-based interactive digital tools is more effective than traditional methods of teaching. While both methods used for instruction showed an increase in content knowledge, the Nearpod technology-based implementation method showed significantly greater gains than the traditional method.

In the final article, *Researching Impact: Measuring Technology Enhanced Outcomes from the NASA Space Science Education Consortium*, Knezek and Christensen first describe the theoretical foundations for empirical research on the impact of NASA Space Science Education Consortium (NSSEC) STEAM Innovation Lab technology innovation activities. The authors then align theoretical foundations with the NSSEC evaluation framework and historical definitions of comparable psychometric constructs, in order to establish guidelines for research in this field. Measurement considerations and examples of three research designs — a) pre-post assessments, b) treatment versus comparison group studies, and c) retrospective pretest (reflecting on before versus after at posttest time) (Pratt, McGuigan, & Katzev, 2000) — are featured as illustrations of those appropriate for the realm of space science education. The authors also present findings from four years of research on the impact of hands-on, technology-infused space science activities in informal learning settings. Findings indicate NSSEC technologies combined with rich engagement opportunities are capable of producing large content knowledge gains and an increase in interest in space science, as well as promoting the development of positive dispositions toward space science.

These articles, taken collectively, illustrate the wide range of activities offered by members of the NASA Space Science Education Consortium and our collaborator, NASA eClips™, with the goal of encouraging students now in school to set their sights on a variety of NASA careers. NSSEC members also recognize that not all young learners excited by NASA-spon-

sored activities will ultimately work for NASA, but many will likely go into some form of STEM career.

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