

STEM AND SPACE: ADVANCING REAL WORLD AEROSPACE TO PRE-COLLEGE STUDENTS

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Abstract

Young children have an innate interest in science. They behold the world around them, are natural questioners, and are not content to simply observe; they must utilize all their senses to make sense of what they perceive. Primary educators can and must capitalize on this interest by immersing students directly into not only hands-on applications, but also into the collaborative and communicative aspects that make up the 21st century skillset. This is particularly true if educators are to encourage and support underrepresented groups to enter STEM fields. This paper seeks to offer project-based STEM activities with a focus on aerospace to excite elementary and secondary students. Moreover, it suggests that creating a science identity early on, particularly for underrepresented populations such as students of color, lower socio-economic status, and females on whole is imperative to increase STEM career participation by using Social Cognitive Career Theory (SCCT) Additionally, there is a focus on equipping teachers to reflect on their own practices as well as offer suggestions for implementing real world STEM in their classrooms. The authors have an active and successful aerospace program and lead the Wolfpack CubeSat Development Team, which is used as a model. Teammates in the middle school level have been selected twice by NASA for their CubeSat Launch Initiative (CSLI), with a third flying last year (2024) with Firefly. Because of the work of older students, younger students are exposed to the real work of space through mentorship. While satellite teams may appear out of reach for school-aged children, there are activities to scaffold the scientific concepts associated with aerospace. Teachers should take part in learning along with their students via professional organizations and professional development.

Keywords: 21st century skills, CubeSats, experiential learning, project-based learning, social cognitive career theory.

1. Introduction

Traditional educational models in America, particularly in the case of STEM coursework, have been notoriously lecture-based, with the focus on the instructor and/or a curriculum that may well not be keeping up emerging trends in a fast-moving industry such as aerospace and engineering. Early on, education in America was considered critical to form and sustain a democracy, creating its citizens to uphold those founding principles (Coulter & Herman, 2020); however, as early as the 1900s, theorists such as John Dewey noted a disconnect between what education was providing and what society actually looked like. Thus began of the Progressive movement, which embodied earlier educational theories like that of Socrates, who valued the role of inquiry. Inquiry can only happen when students are partnered with their teachers in a way that creates real-world opportunities. Coulter & Herman (2020) further point out that if education is to reflect society, “highly autocratic forms of education must change.”

1.1. The Aerospace and Innovation Academy/Wolfpack CubeSat Development Team (AIA/WCDT)

Created by the authors, the Aerospace and Innovation Academy (AIA) and Wolfpack CubeSat Development Team (WCDT) create unique and distinctive STEM opportunities for middle- high school students through an aerospace focus. Since creating the first U.S. middle school CubeSat team in 2015, Simmons led the WCDT to design, build, and launch three spacecraft, and his Wolfpack are building a fourth to be launched in late 2025. Simmons initiated a new paradigm in traditional gifted education: blending strong connections with industry with academia. His unique philosophy, “BLUE-SKY Learning”, coupled with experiential and project-based learning in a real-world setting provides students with myriad ways to communicate their extensive, complex aerospace content.

The first middle school team selected by NASA's CubeSat Launch Initiative, Simmons began in 2015 with a small group whose first mission was "to design, build, test, and fly a CubeSat to space within three years." Through a series of incremental deliverables (emulators, remote sensing tethered balloon payloads, high altitude balloons, etc.) students gained skills and confidence. The 1U WeissSat-1 investigated extremophile bacteria and was launched in 2018 as part of the SSO-A mission. ~13K telemetry packets received during its operational phase. In 2018 The second WCDT mission selected by NASA was the CapSat-1, a 1U designed to validate a capacitor-based electrical power system. Launched in 2022, this CapSat-1 was delivered to the International Space Station for deployment. In 2024 the WCDT saw their third launch with FlipSat-1, a 0.5 hosted payload in the NSL TROOP platform. This mission is evaluating bitflip mitigation strategies and employs micro:bit processors. The Wolfpack's fourth, the WolfSat-1, will launch in late 2025 aboard a Firefly Aerospace Alpha launch vehicle and will investigate the ability of the bacteria *Vibrio natriegens* to digest single-use plastic components on orbit. The authors recognize the successes their program while at the same time acknowledging there are challenges in shaking up the status quo, particularly in the American educational model.

Figure 1. Left to right: NSL's HAB EyePod, HAB launch, WeissSat-1, and SSO-A Falcon-9. Images courtesy of Kevin Simmons.



1.2. The Current State of STEM Education and its Impact on Workforce Development

In 1984, David Kolb built upon this notion with his focus on experiential learning, a method that would build the workforce of the future. A truly progressive model of education is one where innovation takes place by employing project-based learning, a growth mindset, and essentially connecting industry to the classroom. Washko, Edwards, and Washko (2019) note there is a "push to transform engineering education from its traditional roots to a more interdisciplinary approach." They go on to suggest traditional instructional models currently being utilized create "a large gap between the demand for citizens prepared to work in STEM fields and inadequate preparation in both K-12 and higher education." More and more, students report having limited life and career-related skills like creativity and flexibility, which are not taught in traditional curricula. A gap likewise exists between white students and students of color as well as rural and urban students who enter and stay in STEM fields. If more is not done to reduce these gaps, "the United States will lose quality jobs to other nations due to an underprepared workforce" (Sheffield, Morgan, & Blackmore, 2018). Sheffield, *et al* further note experiential, hands-on learning is especially helpful in impacting communities of concern. Their study focused on rural communities, but others have been done on indigenous and other underrepresented communities as well. This shift in educational approach can and should happen with a focus on experiential STEM, and, the authors would maintain, by scaffolding instruction with tools that incrementally build upon themselves to bring about larger learning opportunities. One of the best ways to do this from an aerospace educational perspective is through the use of High-Altitude Balloons (HAB) as a precursor to CubeSats. While CubeSats are a lofty goal for secondary students, lessons using emulators and HABs can scaffold student learning at a lower cost.

1.3. STEM Identity and Underrepresented Populations

There are many factors that add to the issue of underrepresentation in STEM. One area of concern is in science identity formation. In particular, people of color, those from lower socio-economic status, and women continue to struggle to form a personal science identity. These trends for underrepresented groups have been studied from several aspects to determine why students start off interested in the science and math fields but end up not following through with degrees in college, nor pursuing a career once a degree is received. In part, this retention issue is due to a lack of belonging and a lack of a science identity. Using social learning theory and social cognitive career theory, the authors observed that women's preconceived notions of gender roles or identity influence student learning, particularly with regard to what they believe women in STEM fields can achieve. They conclude that women with role models in STEM fields develop enthusiasm and confidence and no longer feel relegated to traditional female stereotypes in STEM careers.

While there needs to be a major overhaul in STEM education that addresses these issues, fostering a science identity early on will go a long way as identity formation starts as early as infancy. In early academics, interest and development are correlated with later educational pursuits. Hachey (2020) points out “schools are powerful spaces for identity work” and it is here, where students who might not experience or have reinforced a science identity at home, may be engaged. Educational reform, particularly with a STEM bent, has long been a goal particularly in the United States where student performance in STEM subjects continues to lag behind that of other countries. Now, more than ever before, there is a movement to embrace the twenty-first century skills, as opposed to the traditional passive learning approach, as an answer to America’s declining STEM performance. To mitigate the issue of student passivity, it is essential to engage students early and often in real-world, hands-on learning that goes beyond the classroom.

1.4. Social Cognitive Career Theory and Experiential Learning

Social Cognitive Career Theory (SCCT) suggests that, early on, students begin to formulate an identity that ultimately is reflected in career choices. To bolster the STEM pipeline, it is imperative to continue the formation of science identity for all students. SCCT is a vocational psychology dealing with “career interests, goals, actions, and performance in relation to domain specific self-efficacy, outcome expectations, as well as contextual and background variables” (Mau, Chen, & Lin, 2019). SCCT shows that students who identify with a certain role, or who “feel” successful in a specific area are more likely to pursue careers in those fields. Erikson’s theory of childhood psychology suggests that children go through several stages in developing an identity. Particularly of note for this research are the competency and fidelity stages which occur from ages 5-12 (Mcloud). Since students are developing an understanding of what they do well (efficacy) along with a sense of fealty to the identity to which they identify (belonging), it makes sense to augment classrooms to provide hands-on experiences that provide both group and personal science identity formation. Children often begin formulating identity long before they attend school based on their roles and interactions at home (Jelic, 2019). Dou, Hazari, *et al* (2019) note many scientists claim curiosity, family encouragement in STEM, and access to STEM media played an important motivating factor in how they viewed themselves as “scientists; however, many underrepresented populations do not have this luxury. Schools can help to close this gap.

David Kolb, in 1984, built upon the pedagogy of Progressivists Dewey and Erikson to create his Experiential Learning Theory, which essentially suggests students learn by “doing.” Students who participate in real-world learning experiences first grasp knowledge in a concrete fashion, then reflect on connections and adjust thinking based on findings, and ultimately students can use their learning in new ways, making it their own. The Aerospace and Innovation Academy provides experiences such as those outlined in this paper through their Wolfpack and Space Clubs and offers the models herein as proven means to augment STEM applications that can also be done in general classrooms.

1.5. High altitude balloons in engineering

Before students can imagine launching satellites, a more accessible lesson comes first. The use of High-Altitude Balloons is not necessarily new to engineering programs around the United States, but they have often mostly been limited to universities and are only in recent years becoming more ubiquitous. McKaig, Caro, Hyer *et al* (2019) note, HABs had their start over a century ago with scientists collecting data from the stratosphere for weather and radiation applications. As time went on, HABs were viewed as an academic tool, but even then, they were somewhat limited to atmospheric science courses where students would design, launch, recover their payloads as well as analyze data and present results (Cheng, Gendron, Ziffle, Gerhard, 2019). Cheng, *et al* further note that post-secondary institutions have been implementing HAB experiments since the early 2000s. In their research, the real-world, experiential learning model engaged students beyond the lesson, and other institutions saw the value of implementing similar experiments with students as early as middle school. Now, there is a general perception that High Altitude balloon missions are reasonably accessible vehicles for younger engineering students to hone their skills related to electronics, communications, and mission planning. Not only are HABs more cost-effective, but they can also be reusable, which adds to their desirability. Additionally, HABs can be launched by individuals without much assistance, which enables more classrooms to employ this tool. Success with HABs often leads to the use of emulators and CubeSats in pre-college settings.

1.6. NearSpace education

As more organizations embrace the importance of HABs as an educational tool, there is an increase in programs that successfully use them. Providing HAB hardware and lessons, NearSpace Education (NSE) created the “Pathways to Space” (PTS) curriculum and technology to better recruit,

engage, and prepare students in the STEM pipeline. Scaffolded for ages 10-college, the PTS central theme is the tiered development of hardware culminating in either HAB missions or CubeSat launches to Low Earth Orbit (LEO). NSE, and parent company NearSpace Launch (NSL), personnel are responsible for hundreds of successful HAB and orbital missions. NSE's HAB System takes students with little to no experience to the point where they interact with their own payloads at the edge of the stratosphere. This system is ideal for training the next generation STEM workforce and can be adapted to meet the training needs of both young adults and pre-college students. NSE's Pathway To Space include the following elements: hardware, curriculum, infrastructure, and Support. Hardware consists of the EyePod element which maximizes customer recovery over 99.9% of the time, lithium batteries, and cameras. Curriculum provided by NSE is tiered and asynchronous content is both scalable for post-secondary and vocational training and aligned to 6th-12th grade Science standards. The infrastructure includes a near real-time dashboard, accessible via internet for both the development phases of hardware and the entirety of the flight. GPS coordinates, altitude, external temperature, rates of ascent and descent, battery voltages, etc. may be monitored in near real-time. NSE also provides FastBus and ThinSat spacecraft platforms which utilize the Iridium network, allowing for coverage at all orbital inclinations. These highly reliable NSL CubeSat chassis are well known for their on-orbit performance.

1.7. The A3Sat project

While the use of CubeSats is a highly effective and disruptive educational tool, the cost and training are often prohibitive. The emergence of CubeSat emulators are logical steppingstones to orbital spacecraft. One such emulator is the A3Sat from the Institute for Earth Sciences in Palmyra Cove, New Jersey. A3Sat refers to Acquire, Analyze, Apply remote sensing data, and provides students a 1U form factor containing a Raspberry Pi, cameras, Enviro+ suite of sensors, dashboard, and accompanying curriculum. The A3Sat Project was designed to broaden pre-college student participation through coding, engineering, data science, geosciences, and electronics by providing a realistic CubeSat A3Sat is also especially affordable for secondary schools, and is designed for use as a HAB, tethered balloon, kite, or drone payload. To further replicate the process of launching and utilizing a CubeSat, a ground station app/software was developed to communicate with the A3Sat while in flight. The desktop software application, compatible with both macOS and Windows, and is able to communicate and transfer various data through Python socket communication. \

2. Material and methods (PBL, experiential learning with a BLUE-SKY philosophy)

The use of HABs and CubeSats as educational tools requires a Project-Based Learning (PBL) methodology. PBL instruction encompasses a variety of elements including Role-playing, real-world scenarios, blended writing genres, multiple reading genres, authentic assessments, authentic audiences, and real-world expertise brought into the classroom (Wolpart-Gawron, 2015). Additionally, the educator authors further employ a BLUE-SKY philosophy, an extreme growth mindset, and a team built around a rigorous task to develop student resilience or grit. By doing so, younger students are prepared to be more academically risk-tolerant and creative.

2.1. HAB mission methods

The general process an HAB mission begins with posing the science question upfront. The science question posed by the students then becomes the mission statement around which all hardware and procedures are derived. The payload development step begins with identifying the sensors that will accomplish harnessing the desired science data. In our example, sensors that will measure temperature, altitude, and incident solar radiation, will accomplish the desired objective. Next the central processor is selected to facilitate connection of the selected sensors to the radio. The selection of the power source along with its control interface follows thereafter completing the payload design phase, in a rudimentary manner. Following the completion of the payload design, acquiring the payload components, building an enclosure, and placing the payload components in it, protecting them from the external environment, constitutes the HAB payload. Finalizing the payload design provided the total mass, which is needed to determine balloon lift, burst height, balloon type, etc. Choosing the flight ceiling altitude is highly mission specific, but in general, HAB missions reach 28-30 km altitudes, with nominal 5 m/s ascent and 7 m/s descent rates. On launch day the students utilize a 'Go-No Go' checklist, re-run simulation software to more accurately predict the landing site and contact the Federal Aviation Authority. Following payload recovery, students download data and analyze it according to the mission statement.

3. Conclusion

To address the “greying” of the American STEM workforce, more must be done to engage students earlier in experiential aerospace. The potential to benefit a larger number of and more diverse students is already being realized with the adoption of HAB and emulator curricula. When combined with the student’s desire to build small satellites such as ThinSats and CubeSats, these systems have been very effective in strengthening student interest towards STEM careers. Ambitious student teams have demonstrated multiple successes through sustained HAB programs, and by launching SmallSats to space. One of the most educationally exciting aspects of the NewSpace Economy is the access to these authentic experiences available to middle and high school students. As industry and academia have embraced the utility, affordability, and scalability of the pico- and nano-satellite form factors, an abundance of financial investments has spawned a cottage industry capable and willing to expand their products and services to even younger student markets. Overall, the use of High-Altitude Balloons as a precursor to satellites in the classroom is exciting and increasingly accessible. When students engage in experiential learning with real-world applications, they retain more content and are more likely to identify themselves in a STEM field. Thus, it is especially important to expose younger students to this kind of learning. While the cost of CubeSats remain out of reach for most educational institutions, HABs offer more affordable but similar learning opportunities. With increased teacher training and adequate funding, these authors envision a strengthening of the STEM pipeline with a strong focus on the robust aerospace industry.

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