

Engagement in Practice: Lessons Learned from Developing K-12 Programming in Naval Engineering

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Introduction

Submarines are crucial for U.S. national security, but the production capabilities of the submarine industrial base (SIB) have been inadequate for decade [1], [2]. Recent findings indicate the industry is over 20% below necessary staffing levels in crucial production roles due to a shortage of qualified STEM talent [1]-[3], with the Department of Defense estimating the need for 15,000 STEM hires annually for the next decade to meet procurement goals [3], [4]. To address this, the Navy has invested in innovative solutions to attract students to naval STEM careers early in their education. This engagement in practice case study outlines the efforts of the UConn-URI Navy STEM Coalition to develop a comprehensive K-12 pipeline by integrating naval technology lessons into STEM pedagogy to showcase career opportunities in the region.

This program builds off similar efforts prioritizing teacher engagement [5], and acknowledges the need for direct student engagement as students decide career paths by middle school and are more engaged by near-peers mentorship [6], [7]. As such, this paper outlines the best practices learned from this DoD-sponsored program's four distinct forms of K-12 engagement: expo-style events, classroom visits, deployable lessons with videos, and summer camps, creating a comprehensive pipeline to draw students into naval applications of engineering.

Background

This study explores various methods for developing student interest in STEM careers to best meet the hiring demands of the naval sector within the program's region. Literature has long suggested such pipelines should be multimodal, with a priority on real world, experiential learning [8], [9]. In rural regions, the Nation Academies finds such multi-modal methods acutely necessary due to the lack of regional resources and funding barriers for student access to quality STEM education [10]. Moreover, this program utilizes the near-peer method in program delivery, providing students with tangible examples of the successful application of STEM education in naval careers [5], [7], [11]. This exposure is vital for inspiring students to pursue STEM paths and seeing themselves as future engineers.

Methodology

The Coalition employs four iterative pedagogical approaches to establish a K-12 pipeline for naval STEM education, increasing in intensity through greater time commitments to immerse students in the naval enterprise. Utilizing near-peer delivery and scalability ensures high engagement and low costs, producing motivated students ready for engineering education and connected to regional partners for internships and jobs. Over three years, 13,507 students have participated (see figures 1-2). The program comprises expo-style events, classroom outreach, remote lesson plans via video, and residential summer programs. Lessons are delivered by the Navy STEM Crew, a 40-member student group with significant female and minority representation, enhancing relatability and inspiration for future engineers [11], [12]. These

dynamics, along with scalability commitments, vary across each program.

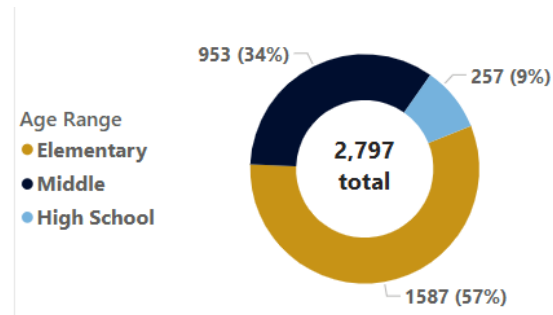


Figure 1 Direct classroom outreach metrics

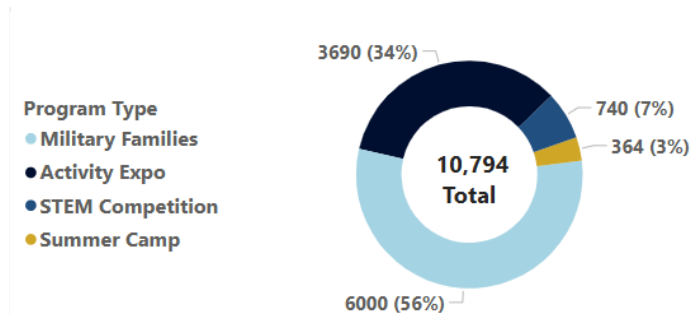


Figure 2 Larger event outreach metrics

A. Expo-Style Events

These shorter events, lasting less than 15 minutes, engage students with simple engineering lessons in larger STEM or naval enterprise settings. Activities like constructing submarines from water bottles or using consumer-grade speakers to teach acoustics ensure high student throughput with minimal consumables. Expo-style events account for the largest outreach volume, represented in the "military families," "activity expo," and "STEM Competition" segments in Figure 2, detailed further in the Results. N=10,430

B. Classroom Outreach Events

In these 1 to 1.5-hour direct STEM activities, Navy STEM Crew members visit regional classrooms across Connecticut and Rhode Island to present naval engineering design challenges aligned with the Next Generation Science Standards (NGSS) and utilizing the near-peer model [7], [13]. This outreach spans from second grade to high school, covering topics such as additive manufacturing and naval construction. Classroom outreach most benefits from the program's scalable methodology, as one lesson has multiple versions across age groups to increase/decrease complexity to meet student ability [9]. N=2,797

C. Full Lesson Plans with Video Component

Expanding in scope, the Coalition partners with national naval initiatives to provide lessons beyond the region, ensuring wider access to naval STEM education. Lessons from Classroom Outreach Events are expanded into comprehensive units with video demonstrations by Navy STEM Crew students, maintaining near-peer delivery [7], [13]. Developed with teachers-in-residence, these lessons align with NGSS and are in the prototype phase without widespread rollout, representing the future direction of the pipeline. N=100

D. Summer Camps

The Coalition supports existing residential STEM camps at the University of Connecticut, offering a week-long camp for middle school girls and a two-week camp for high school students, as well as day camp experiences at the University of Rhode Island. These camps focus on naval engineering, and underwater robotics, co-sponsored with General Dynamics Electric Boat [14]. With the longer duration of camp programs, we can integrate the naval ethos into pedagogy as the informal learning environment increases both student willingness to learn

STEM topics and long-term interest in STEM [15], [16]. Scholarships are provided to offset costs to parents and avoid participant exclusion, covering over half of participants [10]. N=364

Results

A. Expo-Style Events

While the largest throughput events, the depth of STEM engagement is low due to the brevity of lessons, intended to last no more than 15 minutes, with most no more than 5-10 minutes. As such, naval engineering content is surface level. Moreover, most participants in expo-style events are in middle school or younger, necessitating rudimentary pedagogy — time and maturity constraints make it difficult to teach complicated topics such as additive manufacturing.

However, these events are vital for generating interest which leads to pipeline growth. More than garnering student interest in naval engineering, accompanying parents and/or school chaperones learn of the Coalition through seeing these outreach efforts and are encouraged to arrange an in-depth classroom lesson. While one cannot bring a transformative pedagogy to expo events, they remain an effective means of growing a STEM pipeline due to the broad exposure a program can gain in a short period of time, easily engaging over 1,000 students in an evening.

B. Classroom Outreach Events

The National Academies have called for an increase in direct classroom outreach to generate more interest in STEM fields [10], and our experiences have shown indeed brief, direct engagement is the best means of generating student interest. Utilizing the near-peer model rather than faculty as instructors increased engagement, with one teacher remarking after an event how one of their students, a struggling reader, went home over a holiday break to continue a lesson on electrical engineering, and self-taught to solder a gift for their teacher “because I want to be an engineer like [a female Navy STEM Crew lead].”

Several factors are vital to classroom success in building a sustained K-12 pipeline. The most important is the use of the near-peer model [13], [14]. Further, to gain student interest in STEM careers, a pipeline must prioritize middle school to excite students before the traditional point when students self-select out of math and science careers. Repeated exposure is equally critical — developing long-term relationships with districts to facilitate lessons frequently is vital to breaking down the stigma around STEM and developing a deeper understanding of naval engineering, while reaching more students within school systems. In ideal cases, such relationships will encourage districts to explore further STEM integration, such as one district where the Coalition deployed a six-week Navy STEM sequence in collaboration with General Dynamics Electric Boat which inspired an application for grant funding to develop maker spaces for 4th grade classrooms.

C. Full Lesson Plans with Video Component

Full video lessons build off the classroom outreach model, retooling university research into STEM lesson plans for elementary, middle or high school students aligned with NGSS. This pedagogical approach continues the near-peer model, with Navy STEM students leading video

demonstrations, as students follow along in the classroom, often with brief instruction and intervention from their teacher as provided in the lesson plan. This pivot has allowed the Coalition to grow outreach efforts by ensuring lessons can be deployed to schools even when the Navy STEM Crew cannot physically be there. It allows for potential follow-on programming to build up existing science curricula by supplying a video unit and optional modules such as a lab activity or outreach challenge, along with teacher support materials. By integrating with NGSS, the program has ensured that our pedagogy both advances the needs of the naval enterprise and is meeting a teacher's classroom goals.

This component of the pipeline is the Coalition's newest endeavor, and is still in the development phase. However, it represents the future of the program as lessons can be packaged and deployed to endure beyond program cycles, allowing teachers access to the Navy STEM Crew even if there is a funding lapse. Moreover, in partnering with several national Navy workforce development initiatives, the Coalition will be scaling outreach efforts through these lesson plans to bring naval engineering programming to other areas of importance for submarine manufacturing beyond southern New England. This will allow the pipeline to aid in national, as well as regional, workforce development goals.

D. Summer Camps

Summer programs include the most in-depth programming efforts, as all other outreach methods ideally culminate in especially interested students pursuing a summer program to receive hands-on experiences in naval engineering and ultimately make a final career determination within the naval enterprise. Additionally, by prioritizing those populations most underrepresented in STEM, we can ensure we are contributing to the diverse needs of the future naval enterprise [1]. With multiple days of programming to fill, we utilized relationships with industry and Navy partners to give students field trips to manufacturing facilities and a close look at systems they could potentially build. This provides essential context and excites them about a naval future that they can now visualize [15]. This level of exposure is potent, as is apparent in our testimonials, with one middle school participant noting "I'm more confident in my STEM skills because we used them almost every second during the week from inventing our own inventions." A high school participant noted a deeper appreciation of "the amount of creativity, sacrifice and skill it involves to be an engineer" after their participation in summer programming.

Yet, these programs are the most expensive piece of the pipeline to maintain. Not all interested students can afford to attend residential programs which run at-cost where the out-of-pocket expense for parents is over \$1,200. The program has dedicated significant funding to ensure full or partial scholarships to as many students as possible to give access to those who are interested but could not attend otherwise — future programming will be offered for free to all participants for this same reason. For commuter camp experiences, on the other hand, issues of access arise where the communities closest to the university campuses tend to be the most affluent and families are more likely to already have ties to members of the university. Thus, efforts have been made to both provide transportation for communities with higher percentages of underrepresented groups in STEM, as well as to locate a new camp in an urban area, despite the

challenges for program coordinators. Hands-on STEM education is the most effective means of getting students interested, and so any K-12 pipeline should endeavor to have some summer capstone programming to seal the deal on future career prospects with highly-motivated students [15], [16]. Whether a residential or day program, both having a program, and ensuring financial assistance, is crucial for garnering success. Here is where naval engineering careers are formed.

Conclusions

This program was established to address a critical need in the region for a STEM-literate workforce to meet the needs of Navy procurement, especially in the submarine sector [1]-[4]. To meet procurement targets of 15,000 STEM hires annually, the entire industrial base will need to develop comprehensive K-12 STEM pipelines to generate the interest in these career paths necessary to fill jobs. These pipelines require the buy-in and support of educators [5].

As such, the UConn-URI Navy STEM Coalition has pioneered one such pipeline through four distinct program areas to engage students directly. From brief, expo events to generate initial interest and raise awareness to week-long summer camps, this program has engaged over 13,000 students over three years in naval STEM programming. More work is necessary to ensure this pipeline is expanded and can thrive beyond the funding period. We hope the lessons learned here in scalability and multi-modal programming to gather students at increasing levels of interest in STEM education will present a significant framework not only for other regions needing to stand up their own systems for the naval enterprise, but for those looking to generate STEM talent for the myriad generational challenges facing the 21st Century.

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