Bridging Knowledge Gaps in Pre-Service Teaching: Developing a Program in Naval Engineering Education (Evaluation)

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Abstract

Developing a sustainable Navy STEM workforce begins with preparing educators who can effectively connect students to the science and technology behind naval innovation. To address this need, the University of Connecticut (UConn) and the University of Rhode Island (URI) jointly host a four-week summer training program for pre-service teachers (PST). This program focuses on Science, Technology, Engineering, and Math (STEM) education related to submarine manufacturing, regional workforce needs, and national defense priorities. The program builds participants' capacities to integrate authentic, engaging naval STEM content into K-12 instruction. To achieve this, the program offers participants hands-on experience in classrooms, mentorship from veteran teachers, exposure to engineering research labs at universities, and field trips to naval industry partners. While open to all levels of PSTs, the program intentionally targets those focusing on elementary education, as research shows that late elementary to early middle school are formative years when students' attitudes toward STEM often shift, influencing their long-term interests [1]. Furthermore, teacher preparation plays a pivotal role in sustaining student engagement in STEM. Many elementary and middle school teachers report limited confidence in teaching science and mathematics effectively [2], often due to insufficient pre-service preparation and a lack of ongoing professional development [3]. This lack of confidence can unintentionally transmit anxiety or disinterest to students, diminishing classroom curiosity [4]. By providing targeted, context-rich training in engineering and naval STEM concepts, the teacher training enhances both content knowledge and pedagogical self-efficacy, empowering future teachers to create inquiry-driven, engaging learning environments that promote curiosity and confidence in STEM.

During its first two years, program participants commuted daily to either institution and to field sites up to nearly two hours away. Feedback indicated that this extensive travel posed a major barrier to participation and may have limited enrollment. In response, the program is transitioning to a flexible residential model that allows participants to live on campus or commute, improving access, collaboration, and learning cohesion. The program has also evolved pedagogically, expanding beyond the Next Generation Science Standards (NGSS) to incorporate the International Society for Technology in Education (ISTE) and Common Core Math Standards, fostering a more integrated understanding of interdisciplinary STEM instruction within naval contexts. Together, these structural and curricular updates position the training to engage more PSTs, deepen their understanding of naval STEM applications, and strengthen the regional pipeline for a future-ready Navy STEM workforce.

This paper will share key insights from the program's development and implementation, including observations from program staff and feedback from teacher mentors. Lessons learned from the first two program years will be discussed, with a focus on how this feedback informed the evolution of both program content and structure. Specifically, we will highlight how stakeholder input guided the transition to a residential model, the integration of interdisciplinary standards, and refinements in pedagogical strategies designed to enhance teacher confidence and STEM engagement. Future work will also be discussed, including a pending Institutional Review Board (IRB) study to collect and analyze surveys and interviews from past and future participants to assess the programmatic changes, as well as to longitudinally study the 2025 and 2026 cohorts to evaluate the impact of this program.

1 Introduction

Developing a sustainable Navy STEM workforce requires early and sustained student engagement with science, technology, engineering, and mathematics, as well as educators who are prepared to meaningfully connect classroom instruction to real-world engineering applications. At both universities, the Navy STEM Coalition has programs that address multiple areas of interest to improve and increase exposure to the naval STEM fields both internal and external to these institutions. Programming includes K-12 outreach facilitated by near peer college mentors, industry leader seminars connecting undergraduate engineering students to a high level career network, and summer internship programs designed to advance naval scholarship. Among the broad spectrum of target audiences, Navy STEM Coalition prioritizes K–12 teachers, recognizing their daily influence on shaping students' minds and perceptions of STEM disciplines, particularly during late elementary and early middle school, when attitudes toward science and engineering often begin to solidify [5]. However, many pre-service teachers report limited confidence in teaching STEM content, especially engineering, due in part to insufficient preparation and limited opportunities for authentic, practice-based experiences during their training [6].

The Navy STEM Coalition recognizes teacher preparation as a critical dimension in improving K-12 education, providing early and frequent exposure opportunities to STEM disciplines. Thus to address these challenges, both universities, through the Navy STEM Coalition, jointly developed the Undersea Naval Innovation through Teacher Education (UNITE) program, an intensive four-week summer experience designed for pre-service teachers. UNITE focuses on strengthening participants' capacity to teach engineering-focused STEM lessons grounded in naval science and technology, while also broadening their awareness of related career pathways. The program combines classroom teaching experiences, mentorship from veteran K–12 teachers, and exposure to university and industry contexts relevant to naval STEM.

This paper describes the foundational concepts integrated into the original design and implementation of UNITE, gives an example of day-to-day schedule design, shares and reflects on informal feedback and observations gathered during early iterations, and outlines programmatic changes being made in response to participant experiences and relevant literature. This paper emphasizes implementation insights and iterative design decisions intended to strengthen future offerings of the program, as we add more, as informed by outcome assessments.

2 Literature Review

2.1 Importance of Pre-service Teacher Preparation in STEM Education

Teacher preparation plays a critical role in shaping the quality of STEM instruction and student engagement across K–12 classrooms. A substantial body of research indicates that teachers who are well prepared through a combination of content knowledge and pedagogical training are more likely to enact instructional practices associated with effective STEM learning, including guided inquiry, the use of real-world contexts, and strategies that support sustained student interest [7–9]. Importantly, inquiry-based instruction is most effective when teachers are equipped to provide structure, scaffolding, and explicit connections to disciplinary concepts, underscoring the role of preparation in determining instructional quality rather than instructional approach alone [10, 11]. Student engagement in STEM has been consistently linked to hands-on learning experiences, perceived relevance of content, and opportunities to engage in authentic problem solving [12, 13]. These features are central to many contemporary visions of STEM education, but they place significant demands on teachers' instructional knowledge and confidence. As a result, teachers' pre-service preparation becomes a key mechanism through which engaging STEM experiences are made available to students. Early and sustained engagement in STEM is also associated with students' likelihood of pursuing advanced coursework and STEM-related careers later in life [14, 15]. Teachers therefore play a pivotal role not only in shaping immediate classroom experiences, but also in influencing longer-term educational trajectories. When teachers feel equipped with both disciplinary understanding and effective pedagogical strategies, they are better positioned to foster curiosity, persistence, and positive attitudes toward STEM learning [16, 17]. At the elementary and middle school levels, teacher preparation may be especially consequential. This developmental period is marked by shifts in students' motivation, identity, and perceptions of competence, during which beliefs about ability and interest in STEM subjects become more stable and increasingly influential [5, 18]. Teachers who are prepared to deliver engaging, supportive, and confidence-building instruction during these years may help counteract early disengagement and promote sustained interest in STEM over time.

2.2 Pre-service Teachers' Confidence and Preparedness to Teach STEM

Despite the recognized importance of high-quality STEM instruction, many pre-service teachers report feeling underprepared to teach science, mathematics, and engineering effectively. This sense of unpreparedness is particularly prevalent among pre-service elementary teachers, who often complete relatively limited coursework in STEM content and instructional methods as part of their preparation programs [6, 19]. Research suggests that insufficient pre-service preparation is closely tied to low self-efficacy for teaching STEM subjects [20, 21]. PSTs frequently report concerns about gaps in their content knowledge, discomfort facilitating open-ended inquiry, and difficulty translating abstract STEM concepts into developmentally appropriate instruction [22, 23]. These challenges are often exacerbated by limited opportunities for authentic practice, as many pre-service programs provide few sustained, classroom-based experiences focused specifically on STEM instruction [24, 25]. As a result, novice teachers who feel underprepared may rely heavily on scripted curricula, reduce instructional time devoted to STEM, or avoid more cognitively demanding instructional approaches altogether [26, 27]. In high-stakes accountability contexts, these tendencies may be further reinforced. Without targeted support during pre-service preparation, such instructional patterns often persist into in-service teaching, shaping classroom practice well beyond the initial years of the profession [28, 29].

2.3 Teacher Attitudes, Confidence, and the Transfer of STEM Anxiety to Students

Teachers' attitudes toward STEM, including their confidence, anxiety, and personal interest, play an important role in shaping students' classroom experiences. Teachers with low confidence in STEM subjects are more likely to limit instructional depth, avoid challenging content, or approach lessons with reduced enthusiasm, all of which can influence how students perceive STEM learning [6, 30]. Research indicates that students are sensitive to teachers' affective cues and may internalize teachers' expressed attitudes toward academic subjects [17]. When teachers convey anxiety or discomfort with STEM, these signals can shape students' beliefs about STEM as difficult, unapproachable, or misaligned with their own abilities. This dynamic is particularly concerning in elementary classrooms, where students are still forming foundational beliefs about competence and academic identity [31, 32]. Conversely, teachers who demonstrate confidence, curiosity, and openness to uncertainty can foster classroom environments that encourage exploration, persistence, and productive struggle. By modeling comfort with problem solving and sense-making, teachers help normalize the iterative nature of learning that is central to STEM disciplines [13]. These findings highlight teacher confidence not only as an individual professional attribute, but also as an important mechanism through which student engagement and persistence in STEM are supported.

2.4 Implications for Targeted, Context-Rich Pre-service STEM Programs

Taken together, the literature points to a clear need for PST preparation programs that intentionally integrate STEM content knowledge, pedagogical skill, and teaching self-efficacy. Traditional coursework alone is often insufficient to address these interconnected dimensions, particularly for PSTs with limited prior exposure to STEM fields [24, 25]. Emerging evidence suggests that targeted preparation models incorporating authentic contexts, hands-on learning, mentorship, and classroom-based practice can help address gaps in PSTs' confidence and preparedness [11, 33]. By situating STEM instruction within meaningful, real-world applications, such programs may support both conceptual understanding and instructional competence. These findings provide a strong foundation for examining PST training models designed to enhance confidence, engagement, and instructional quality in STEM. Programs that focus on early educational stages and leverage interdisciplinary, applied STEM contexts may be particularly well positioned to influence both teacher development and student outcomes, especially during critical periods of motivational and identity development.

3 Program Context and Original Design

The Navy STEM Coalition seeks to build a regional community of naval stakeholders from academia, industry, and federal and state agencies to support STEM workforce development for the regional and national Navy enterprise. Among the Navy STEM Coalition's programs, UNITE is a four-week summer program jointly developed by both UConn and URI, first piloted in Summer 2024. The program was designed to balance instructional preparation, classroom practice, observation, and reflection. Navy STEM Coalition administrators engaged contracted teachers and teachers-in-residence to collaborate on developing a structured sequence of activities that progressively built PSTs' confidence in leading engineering-focused STEM lessons and managing classroom dynamics. The mentor teachers were either teachers-in-residence or contracted teachers, depending on the university; for the purpose of this paper, mentor teacher (MT) will be used when describing both contracted teachers and teacher-in-residence henceforth.

The teacher-in-residence model has been used successfully for many years at the University of Rhode Island, where STEM teacher leaders who are highly proficient with hands-on science curriculum are invited to leave the classroom for 1-2 years and work directly with university researchers to deliver workshops for a larger body of teachers in partner districts. As a part of UNITE's activities, starting in 2023, specific teachers-in-residence have been dedicated to the development, implementation, and support of STEM modules that link current naval science and engineering research to K-12 science concepts and NGSS standards. At the University of Connecticut, contracted teachers who helped with this program were experienced K-12 classroom teachers and served a similar function to teachers-in-residence. This paper focuses on the activities administered in Summer 2025 as the initial pilot programming in Summer 2024 was less developed.

The program is open to pre-service teachers (PSTs) from across the region, with particular emphasis on those preparing to teach at the elementary level. UNITE was designed as a single, non-residential program and it was implemented concurrently at both university campuses to provide exposure to differing K-12 standards and regional locales. While collaboratively developed by both universities, the program was administered at each institution during the summers of 2024 and 2025 with parallel schedules and aligned curricula. Each campus hosted a distinct cohort of PSTs, resulting in two groups participating simultaneously in the same program. The 2025 program included 10 participating PSTs: six from the UConn cohort and four from the URI cohort. Opportunities for cross-campus collaboration were incorporated, with PSTs from both universities participating jointly in selected pedagogy sessions and field trips, at least one to two times per week. Program administrators prioritized collaboration between the two cohorts to preserve program coherence and to provide exposure of both regional locations to all participants.

Additional collaboration among PSTs is planned for UNITE 2026, as all participants will spend the first two weeks of the program at the URI campus. During the final two weeks, participants may remain at URI or elect to complete the program at UConn. Following the success of UNITE 2025, enrollment more than doubled, with 24 PSTs accepted into the 2026 program. To accommodate this growth, program administrators implemented structural adjustments while maintaining opportunities for PSTs to experience the educational systems of both states.

Table 1 presents the original UNITE schedule prior to any programmatic revisions. The schedule reflects the program's initial approach to integrating teaching practice, observation, and exposure to naval STEM contexts over the four-week period.

4 Program Implementation and Facilitation

UNITE hired MTs to assist with program development and to instruct PSTs throughout the program. Navy STEM Coalition members and MTs worked collaboratively to create the schedule for pre-service teachers to develop their STEM teaching skills and broaden their understanding of naval science and engineering. This schedule is intended to provide PSTs with ample opportunities to develop their teaching abilities while broadening their understanding of naval STEM concepts so that they can inform their future students about career opportunities.

During the program, Navy STEM Coalition administrators were responsible for scheduling, coordinating external partnerships, and managing logistical needs, while MTs delivered the

Table 1: UNITE Schedule Sample

Program Sequence	Focus Area	Purpose of Activities	Key Activities
Week 1	Orientation / Introductions	Acclimate PSTs to program expectations and lesson materials	• Allow students to introduce themselves and discuss goals • Provide program overview • Explore lesson materials used in K-6 engineering-focused lessons
Week 2 & Week 3	Rotational Teaching: Additive Manufacturing Lesson & Build a Boat	Allow PSTs to practice leading an engineering-focused lesson they can translate to their future class (Capobianco, 2021)	• PSTs take turns leading lessons and providing classroom support • MTs lead debrief session to discuss successes and constructive criticism of lesson delivery and classroom management
Week 3	University Exposure & Field Trip	Provide examples of future field trips PST may lead to teach students about naval technology	• Pedagogy lesson led by MTs • Tour of URI labs • Tour of URI nuclear reactor
Week 3	Classroom Observation: Naval Activity for Kids (Grade 4)	PSTs learn about classroom management and the delivery of an engineering- focused lesson through observation	• Review and discuss engineering-focused lesson prior to student's arrival • Observation of classroom behaviors and lesson delivery
Week 4	STEM Lesson Development	Allow PSTs the opportunity to practice developing lesson plans	• PSTs and the MT discuss the development of a lesson plan • PSTs develop lessons plans individually • Peer review and revision session
Week 4	STEM Lesson Presentation	Provide PSTs opportunity to practice administering their lesson plans with constructive feedback	• PSTs present their lessons to their peers, MTs, and program leaders • Debrief and provide feedback for each PST's lesson and delivery

instructional content and guided the classroom experience of PSTs. MTs played a central role in supporting the participants throughout this program. While the Navy STEM Coalition's administrators supported program logistics, this staff did not have expertise in K-12 education instruction. Thus, contracted K-12 teachers were hired to work alongside the teachers-in-residence to lead instruction on activities such as lesson planning, classroom management, content delivery, and providing feedback to PSTs based on their performance administering engineering-focused lessons in K-12 classrooms.

Beyond the formal schedule, UNITE relied on a facilitation model that emphasized collaboration between program investigators, administrators, and MTs. MTs supported participants throughout the program by observing lesson delivery, and facilitating structured reflection sessions. These debriefs provided opportunities for participants to discuss successes, challenges, and classroom management strategies in a supportive environment. Additionally, MTs led pedagogical lessons and facilitated discussions with PSTs. These sessions focused on effective strategies for leading STEM lessons and maximizing the educational value of STEM field trips for future students.

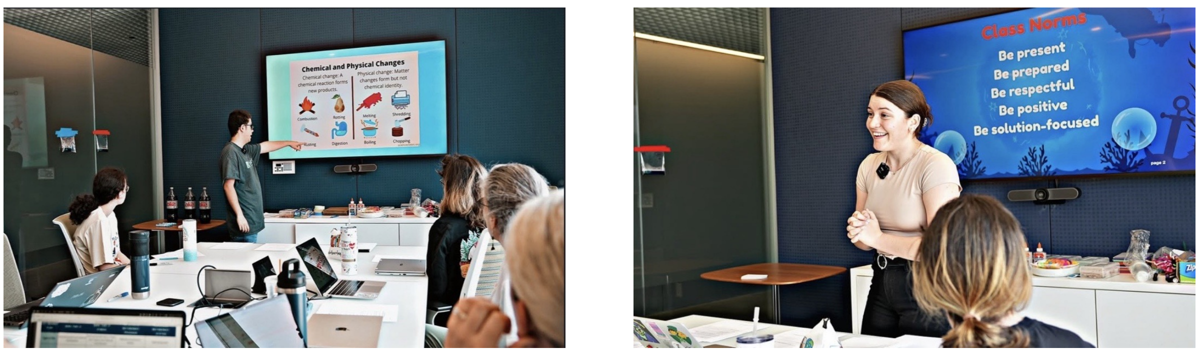

Figure 1: PSTs Practicing Lesson Delivery

Rotational teaching activities allowed pre-service teachers to take turns leading engineering-focused lessons while peers provided classroom support. Observation days enabled participants to watch experienced teachers deliver similar lessons to K–12 students, offering insight into classroom dynamics and instructional pacing. Field trips to university laboratories and related facilities were incorporated to expose participants to potential future learning environments they might leverage as practicing teachers.

While the program design aligned with practice-based teacher education principles, implementation required participants to navigate frequent travel between sites. This logistical structure influenced the daily experience of the program and emerged as a notable factor during informal feedback discussions.

5 Informal Feedback and Observed Outcomes

On the final day of the program, the program administrator collected informal feedback from the PSTs through a semi-structured group discussion. During this session, PSTs responded to questions posed by the administrator in an open group format and were encouraged to share as much as they felt comfortable. The administrator documented the participant's remarks throughout the discussion. Although no formal assessment instruments were used, several consistent themes emerged regarding participant experiences and elements of the program design.

Figure 2: Contracted Teacher Providing Feedback

PSTs highlighted the value of hands-on teaching opportunities and structured feedback in supporting their instructional development. Opportunities to lead lessons and receive immediate feedback were viewed as highly beneficial. However, some PSTs expressed a desire for greater variety in how feedback was delivered. While the PSTs greatly appreciated feedback from the MT, they felt the feedback discussions became repetitive over time.

Another theme identified by the program administrator was that PSTs found great value in the program's field trips. Throughout the program, participants visited several off-campus sites, including the Submarine Force Museum, URI's nuclear reactor, and the shipyard for a major naval contractor. PSTs reported that these experiences broadened their understanding of careers and applications within the Naval STEM field.

Additionally, many of the PSTs voiced that the travel requirements were burdensome. Although participants were reimbursed for trips exceeding 30 minutes from their campus, they felt that the overall amount of travel was excessive. Many PSTs noted a preference for the program to provide transportation for off-campus excursions.

These evaluation findings informed subsequent discussions among program leadership regarding potential refinements to program structure and delivery.

5.1 Ideal Practices

Based on informal feedback, PSTs reported that the field trips and excursions outside the classroom were highly valuable. In addition to the previously described off-campus sites, the program leveraged university laboratory resources at both institutions. PSTs toured engineering and oceanography laboratories while discussing ongoing research with faculty. These experiences provided PSTs with firsthand exposure to a wide range of STEM disciplines and related career pathways.

PSTs indicated that these excursions broadened their understanding of naval STEM careers and professional opportunities. As future educators, PSTs recognized the importance of this knowledge in shaping young students' perceptions of naval STEM and reported increased confidence in their ability to share this information with future learners. Additionally, PSTs gained concrete examples of field trips they could implement in their own classrooms. Throughout all field trips and laboratory tours, PSTs were encouraged to envision how these experiences could be adapted for their future students. Given the overwhelmingly positive feedback and alignment with program goals, UNITE will continue to include off-campus excursions for future cohorts.

6 Program Revisions Informed by Feedback and Logistics

In response to participant feedback and implementation observations, UNITE is undergoing several structural refinements. A key change involved transitioning toward a more flexible residential model, allowing participants to live on campus or commute, with the goal of reducing travel burden and increasing opportunities for collaboration and community building.

In addition to feedback from the PSTs, program administrators identified excessive travel to off-campus locations as a concern. PSTs were required to drive their personal vehicles to field trip sites and partner elementary schools throughout Connecticute and Rhode Island. Travel times ranged from approximately 20 minutes to over two hours during programming hours. Furthermore, some PSTs commuted up to 45 minutes to campus daily from their residences. Program administrators and MTs agreed that the extent of independent, required travel hindered learning opportunities for PSTs, as frequent and lengthy commutes often resulted in tardiness and reduced instructional time.

Despite these challenges, both PSTs and program administrators reported that the off-campus experiences were a highlight of the program. To balance the benefits of experiential learning with the need to reduce travel demands, the program has transitioned to a split-site model between the University of Connecticut and the University of Rhode Island, with housing provided at both campuses. This restructuring is intended to decrease the amount of time PSTs spend commuting to campus and traveling to field sites by eliminating cross-state travel between CT and RI; the split design maintains the original intent of exposing teachers to differing state standards and regional locales. The programmatic change, driven directly by participant feedback, will be piloted during UNITE 2026.

Additionally, curricular adjustments are also being made to strengthen alignment with multiple educational standards, expanding beyond the Next Generation Science Standards to include include technology and mathematics standards such as the International Society for Technology in Education (ISTE) and Common Core Math Standards. These changes are intended to support a more integrated approach to STEM instruction and better reflect the interdisciplinary nature of naval engineering.

7 Conclusion and Future Work

Future iterations of UNITE will incorporate more systematic data collection to better understand participant experiences and program impact. A pending IRB study will enable the collection and analysis of interviews and other qualitative data from current and past participants. Longitudinal work is planned to examine how program participation influences teaching practices and confidence as participants enter the classroom.

Future research will also explore how specific structural changes, such as the residential model and revised scheduling, affect participant engagement, collaboration, and perceived preparedness. These efforts will contribute to ongoing refinement of the program and inform broader discussions around practice-based STEM teacher preparation.

The Undersea Naval Innovation through Teacher Education program, UNITE, represents an effort to prepare pre-service teachers to integrate engineering-focused STEM instruction grounded in naval science and technology. Early implementation highlighted both strengths in the program’s practice-based design and opportunities for structural improvement. By reflecting on informal feedback and drawing on relevant literature, the program continues to evolve in ways intended to better support participant learning and engagement.

This paper contributes an implementation-focused perspective on the iterative development of a STEM teacher preparation program and underscores the importance of responsiveness to participant experience in educational program design.

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