Developing Workforce for the Blue Economy: Creating a Pipeline from K-12 to Higher Education

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Abstract

Low enrollment and high attrition rates in science, technology, engineering, and math (STEM) based degree programs have created a workforce problem in industries like shipbuilding and repair, which are essential for national security. Part of this problem can be attributed to pedagogical issues like the lack of engaging hands-on activities utilized for science and math education in middle and high schools. Lack of student interest in technical careers can also be attributed to a lack of an integrated approach in teaching math, science, and technical education. Lack of a strong foundation in math and science at the school level has led to large-scale flight and attrition from STEM-based career tracks in higher education. Engineering and engineering technology programs throughout the nation have observed declining graduation rates and quality of incoming students. To engage students' interest in a technical career path, students must establish a link between the theoretical knowledge and its application to solve real-life problems early in their learning experience. Project-based activities have a proven record as an instructional tool. The effectiveness of such activities as a pedagogical tool has been supported by research in acquiring and retaining knowledge. Here we propose a new platform called The Blue Tech Project to offer project-based activities to a vast group of audiences in academia and industries. The Blue Tech Project attempts to address the workforce issue for the blue economy by developing project-based learning kits and associated instructional modules along with a broad range of extra-curricular activities to engage students in STEM tracks and increase awareness about blue economy careers. The teacher training component of the project will provide training in using and implementing these modules. In this article, we present the motivation behind developing these project-based learning (PBL) modules, issues related to implementation, and results from student and teacher workshops.

1. Introduction

The concept of the "Blue Economy" is gaining traction among government, industry, and nonprofit sectors as an organizing principle that captures the interplay between economic, social, political, and ecological sustainability of the oceans. The World Bank defines the blue economy as "sustainable use of ocean resources for economic growth, improved livelihoods, and jobs and ocean ecosystems health" [1]. Based on the Organization for Economic Co-operation and Development analysis, the global Blue Economy is projected to double in size to $3 trillion by 2030, including solid growth in emerging sectors such as alternative energy, digitalization and automation of transportation and port operations, food security, and coastal resilience. The global economy is closely connected to the Blue Economy, with 90% of the world's goods being traded across the ocean and much of tomorrow's food and energy security depending on ocean-related activities. Investments in a sustainable ocean economy are not just suitable for the sea but also essential for the country's development. For example, investing $2.8 trillion today in just four ocean-based solutions—offshore wind production, sustainable ocean-based food production, decarbonization of international shipping, and conservation and restoration of mangroves—can yield a net benefit of $15.5 trillion by 2050, a benefit-cost ratio of more than 5:1 [2].

In 2018, the Blue Economy contributed an estimated $373 billion to the nation's gross domestic product in the US, supporting 2.3 million jobs and growing faster than the nation's economy in its entirety. The economic activity from America's seaports alone grew from 2014-2018 by 17% to $5.4 trillion, comprising nearly 26% of the nation's $20.5 trillion gross domestic product (GDP). Furthermore, coastal counties in the US are home to 127 million people or 40% of the population. The GDP of American coastal counties is such that it ranks third in the world in GDP, behind only the United States and China [3], [4].

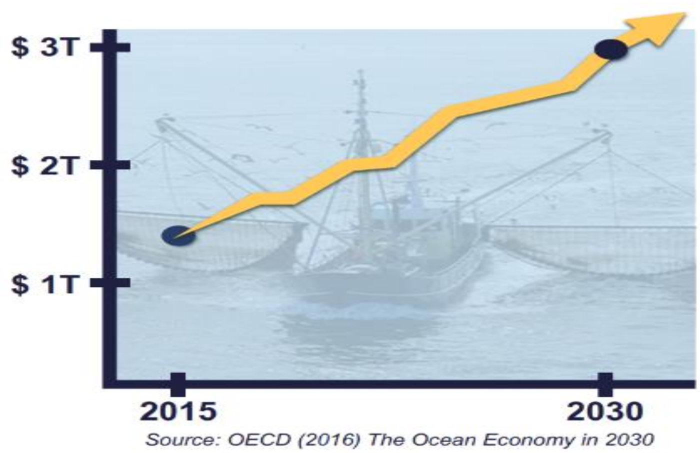

Fig. 1. Projection of the America's Blue Economy [3], [4].

Texas A&M University at Galveston, in collaboration with the marine industry and five local school districts, is improving STEM preparation using innovative experiences for students and teachers in the nation's major shipbuilding and repair areas through the Blue Tech project. This project will be serving 60 students in grades eight through twelve, over three years, by providing 144 hours of instruction and hands-on learning experiences in the fields of marine engineering and physical sciences with a shipbuilding focus. Blue Tech's progressive curriculum covers foundational skills and knowledge of basic physical sciences related to ship design & building, applying these principles in a culminating ship design competition. The curriculum is enriched with program activities such as field trips to shipbuilding and repair companies, marine science museums and career day events. The program includes eight Saturdays during academic years, with an additional two-week academy each summer.

2. Proposed Blue Tech Project

We need to transform the teaching and learning environment to improve student learning by applying proven strategies to enhance student knowledge of STEM and ICT careers, thereby motivating them to enter STEM careers. Relevant data on students and teachers are collected from selected school districts: a) STAAR scores for individual high schools in math and science, and b) data on teachers with graduate degrees. Analysis of the STAAR assessment data of the participating school districts consistently reveals the lower performance of the high school students, particularly among the subgroups, in physical sciences and algebra compared to the state averages and students from more affluent regions of Texas.

Table 1**.** STAAR testing results.

School District	% meets grade level standard or above	Econ Disadv	Science scores	Science Econ Disadv	Math Scores	Math Econ Disadv
Friendswood	83%	67%	89%	70%	73%	64%
Clear Creek	65%	47%	64%	47%	61%	54%
Dickinson	56%	50%	68%	60%	55%	53%
Texas City	49%	44%	63%	58%	40%	38%
Ball	42%	36%	44%	35%	34%	30%

As shown in Table 2, in the cases of an average score and subject tests for math and science, economically advantaged students have a significantly lower percent that meets the standard than the average student. This means a gap between the average student and those financially disadvantaged needs to be completed, especially in the Galveston area.

It has been observed that many poor small- and medium-sized rural districts are affected by the same factors that affect large urban systems, including children from low-income families, high percentages of minority ethnicities, scarce resources, insufficient numbers of highly qualified teachers, high teacher turnover, and low academic performance and wide achievement gaps on state and local assessments [5]. The partnering school districts, Galveston and Texas City, have significant Hispanic and Black Underrepresented Minority (URM) students. In addition, Texas City and Dickinson School are rural districts and have high poverty rates.

The poverty rate in Galveston is significantly higher than in other surrounding cities at nearly 20%. The median individual income is around $23,000 a year, which is also either the same or lower than the surrounding cities. When broken down by race, African Americans have the least household income, followed by Asian and then Hispanic or Latino. This further exemplifies the needs of the minorities in the surrounding cities. In Galveston County, Galveston has the second-highest population. This means Galveston has one of the highest populations and poverty rates among their communities [6].

Ball High School, located in Galveston ISD, has about 2,000 students, and 76.4% of them are considered economically disadvantaged. Texas City has about 1,800 students ranging from 9th to 12th grade and is predominantly Hispanic. Here, 64.7% are considered economically disadvantaged. Dickinson, Texas, was shown to have the second-highest poverty rate of cities near Galveston. Their central high school has around 3,100 students, 59.2% considered economically disadvantaged. Friendswood High School has approximately 2,100 students enrolled, 8.0% of which are economically disadvantaged, and 1.1% are English language learners [7]. Thus, the Blue Tech project will recruit from URM groups that are also financially disadvantaged.

3. Project Design

The goals of Blue Tech will be accomplished by providing professional development, instructional materials, online training, and tools for a cohort of 80 educators in high-need schools in Texas, from the greater Galveston, Houston, and coastal regions of southeastern Texas. All teacher summer workshops will be conducted at TAMUG. Guest lectures and training will be online using interactive video conferencing. Teachers will be provided with Blue Tech instructional modules and SeaPerch kits for classroom implementation. The teachers will (1) participate in workshops on research-based instructional practices and implement them the following year, (2) demonstrate the SeaPerch created in a Saturday competition during summer.

Further, the Blue Tech project will train 60 students in four Saturday Academies each semester (eight Saturdays/year, 64 hours of instruction during the school year). Student participants will (1) complete project-based instructional modules in a two-week-long summer academy; (2) independently practice skills during summer; (3) participate in eight Saturdays hands-on academies on Blue Economy related topics, including marine cybersecurity, offshore clean energy, marine robotics, marine shipping, and marine information and communication technology; (4) receive metacognitive, and counseling services; (5) field trips to Blue Economy companies and cruise aboard the TAMU research vessel; and (6) participate in a marine engineering competition during summer. A stipend of $400 will help attract and retain students in the program.

In Blue Tech, Texas A&M Galveston will be partnering with five local independent districts in the greater Galveston, Houston, and coastal regions of southeastern Texas in the SEI R&D project of the ITEST-STEM proposal. The goal is to expand and improve STEM innovation to a broader audience. The targeted population will be students and teachers in racially diverse and socially and economically disadvantaged schools. In addition to traditional classroom preparation, this project will provide formal and informal educational experiences, thereby enhancing the existing framework and use of technology. Focus areas include Marine Technology and STEM careers in Blue Economy in engineering & technology fields.

Table 3 shows the structure and different topics covered in one year through this program. It is enriched with marine-centered STEM modules to increase student awareness about careers in marine engineering technology to build up a workforce for the growing Blue Economy. Out of the five high schools, 20 teachers (4 per school) and 60 students (3 students per teacher) will be chosen to participate in this four-year program. They will receive a two-day professional development summer workshop and 10 hours per semester of online training to prepare these teachers. They will be compensated for their time with a stipend of $600 and 15 CEU credits. All materials will be provided, including one SeaPerch Underwater Remotely Operated Vehicle (ROV) kit and twelve module packages. The training will provide them with the knowledge they can implement in all their students. This will extend the impact of this program even further. Students will attend four Saturday Academies per semester, translating to eight Saturdays an academic year with 64 hours of instruction. The summer academies will include two weeks of project-based learning and immersive marine science experiences with 80 hours of learning experiences. This will consist of field trips to Blue Economy Companies and Marine Museums. Transportation for the summer academies will be provided as well as food.

Table 3. Instructional modules for Blue Tech.

Modules & Focus Areas	**S** **Science** (Week-Long Summer camp)	**T** **Technology** (Instructional Modules & Lab)	**E** **Engineering** (Instructional Modules & Lab)	**M** **Math** (Instructional Modules & Lab)
Module 1	Sustainable Shipping	Wind Power Generation	Marine Electrical Power Systems	Math in Ship Building
Module 2	Oceanography	Marine Robotics	Marine Simulators	Math in Shipping
Module 3	Ocean Conservation	Solar Power Generation	Offshore Structures	Math in Marine Electronics
Module 4	Coastal Ecology	Cybersecurity of Shipboard Systems	Ship Propulsion	Math in Clean Energy

This Blue Tech project builds on the success demonstrated by the PI’s previous project, MarineTech, in Virginia. MarineTech was successful in (1) increasing students’ literacy of math, science, and engineering concepts; (2) fostering students’ practice through project-based learning leading to engineering competitions; and (3) piquing student interest in STEM through hands-on exercises and team activities. The proposed project expands the focus to STEM careers in Blue Economy. It offers developing twelve instructional modules and innovative immersive marine science experiences to supplement the curriculum.

To increase the involvement of underrepresented students in math, science, and technology, educators need to change the way these subjects are taught. Through collaboration, educators in high schools will be trained to improve their instruction by creating learner-centered classrooms that require students to build and develop their critical thinking skills, resulting in increased self-confidence.

4. Conclusions

We intend for this project and investigation to motivate and support engineering educators and faculty members in the field of Marine Engineering. Based on the presented findings, we infer a vital need to have a platform to conduct systematic training via project-based courses for senior high school students as well as junior undergraduate students to become more familiar with the strong potential of the marine industry in the future of the economy. While this paper shows our progress on the project development related to supporting all students, especially the underrepresented students on the horizon of the Blue Economy, it did not systematically evaluate the challenges ahead of these groups. Future research can assess and examine the economic and technical challenges to support all student groups in the blue economy.

In addition, future research can evaluate the impact of math and physics knowledge levels in the social groups that are systematically marginalized in engineering education. Therefore, we see this project as a first step to clarifying the issues ahead of the Blue Economy and offering solutions for improvements.

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