Development of Naval Challenges Motivated High School Curriculum Units

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Abstract

This work in progress paper describes the current status of a multiyear Office of Naval Research (ONR) funded effort to enhance students' science knowledge and understanding of the importance of STEM to the Navy and Marine Corps. The project addresses the Department of the Navy STEM workforce pipeline issues by utilizing pedagogical techniques that focus on the motivations and life goals of millennials and generation Z. Curriculum units are being developed that highlight the positive impacts of DoN STEM careers on society and leverage students' desires to "make the world a better place" to encourage them to pursue careers in STEM in general and DoN STEM careers in particular. Each unit focuses on a STEM challenge faced by the DoN. The program utilizes area high school STEM teachers to guide topic selection and collaborate in lesson development. Teacher involvement early in the process is key to the success of the project by identifying standard alignment and promoting usability.

Keywords

Altruism, Grand Challenges, Community, Navy

Introduction

The National Academy of Engineering (NAE) Engineering Grand Challenges (EGCs) is a list of 14 engineering-related challenges (Table 1, left column) that, if solved, would have a profound societal impact. These challenges were developed as an extension of the NAE efforts to portray engineering as an important and exciting profession that has profound impacts on society.[1] This movement, exemplified by the *Changing the Conversation*[2, 3] is intended to address various human resource challenges to the field of engineering. First, there is a lack of interest in engineering among U.S. college students that limits the number of U.S. citizen students entering undergraduate and graduate engineering programs.[1, 4, 5] Second, there is a need to increase the diversity of students engaging in engineering majors with respect to gender, race/ethnicity, and socioeconomic status.[5, 6] This work in progress leverages and extends the concept of the NAE EGCs to DoN STEM Challenges and the Naval Research and Development framework. While a list of DoN STEM Challenges does not exist in the same form as the NAE EGCs, mapping research focus areas from the Naval Science & Technology (S&T) strategy[7] to the EGCs provides a ready framework for utilizing Naval research priorities as examples of EGCs to promote student interest (Table 1).

The NAE's efforts reflect an implicit theory that there is a perceived mismatch between some students' preference for careers that serve a prosocial or altruistic goal and the opportunities of engineering, which may be perceived as a field that is better suited to fulfill status and

Table 1: Naval S&T Research Areas (not an exhaustive list) mapped to NAE EGC.

NAE EGC	Related Naval R&D Focus Area
Engineer the Tools of Scientific Discovery	Navigation and Precision-Timekeeping, Solid State Electronics, Nanometer Scale Electronic Devices and Sensors
Provide Access to Clean Water	Small Unit Water Purification, Submarine and Ship Water Supply, Remote Theater of Operations
Provide Energy from Fusion	Energy Security
Make Solar Energy Economical	Advanced Naval Power Systems, Energy Security, Reduce Fuel Required at Sea, Unmanned Air/Sea/Ground Vehicles
Reverse-Engineer the Brain	Biorobotics, Cognitive Science and Neuroscience, Bio-Engineered Systems, Intelligent and Autonomous Systems
Prevent Nuclear Terror	Peacekeeping, Threat Mitigation
Engineer Better Medicines	Warfighter Health and Survivability, Casualty Care and Management
Enhance Virtual Reality	Warfighter Training and Simulations, Remote Medicine, Autonomous and Unmanned Vehicle Mobility
Restore and Expand Urban Infrastructure	Logistics for Material Equipment and Troop Movement, Structural, Mechanical, and Electrical Support Infrastructure
Secure Cyber Space	Electronic Warfare, Cyber Security & Information Operations
Develop Carbon Sequestration Methods	Air Quality in Submarines, Meteorological Directorate
Advance Health Informatics	Warfighter Health and Survivability, Casualty Care and Management
Advance Personalized Learning	Manpower, Personnel, Training and Education, Instructional Design and Technology
Manage the Nitrogen Cycle	Environmental/Meteorological, Decompression in Divers

individualistic values. This is consistent with the theory of goal congruity, Figure 1.[8, 9] Goal congruity predicts that students will experience greater interest in or commitment to a career field when there is an alignment of their career values and their perceptions of the field regarding what outcomes they can expect or with which values the career aligns. The NAE's approach is designed to challenge common misperceptions of engineering as individualistic and increase the number and diversity of students interested in engineering college majors and careers. Several studies have found millennial students are particularly motivated when course content is put in a real-world context and related to societal impact.[3, 10-12] In a related line of work, a growing body of literature indicates that women are more likely to prefer pro-social or altruistic career values, and therefore perceive engineering as a field that is less supportive of these values and offers fewer affordances to engage these values.[9, 13, 14] These altruistic goals may also be more common among some race/ethnicity groups that are underrepresented in engineering.[15] Therefore, it is essential for initiatives that seek to increase the size and diversity of the engineering degree pool to address this perceived lack of altruistic and communal affordances in engineering. The NAE EGCs support efforts to change perceptions of engineering in that they help the public understand more concretely how advancing engineering contributes to advancing society and provide concrete examples of how an engineering career meets communal and altruistic goals. By extension, adapting the EGCs for the Naval context was expected to enhance the interest of students in STEM careers in general and the positive views of Naval STEM careers in particular.

Activities and Status:

To date, eight curriculum units have been developed in conjunction with area high school teachers. The titles of the units are (1) Emergency Water Purification, (2) Alternative Power for Ships, (3) CO_2 Sequestration and Submarine Air Quality, (4) Starlight and Spectroscopy, (5) Nuclear Power Submarines, Half-life, and Safety, (6) Designing Advanced Arresting Gear, (7) UV Irradiation and Shielding, and (8) Mapping the Sea Floor. These units include STEM concepts, introductions to Navy relevance,

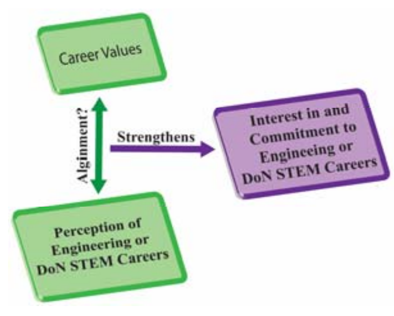

Figure 1: Simplified Theory of Action, Goal Congruity.

and hands on experimental and design activities. The units are in various stages of testing and evaluation at area high schools.

As an example, the Advanced Arresting Gear (AAG) module is focused on teaching physics concepts through the systems used for carrier landings. The module covers motion and energy concepts, including conversion from potential to kinetic energy, the relationship between velocity, position, and acceleration, rotational moments of inertia, and fluid viscosity. The activities utilize a PASCO smart cart and track system, and a custom 3D printed tank and wheel. The activity involves students measuring velocities as the cart rolls down an inclined track and along a level track segment. The students record velocity data and calculate energy and energy conversion (potential to kinetic). The system is then modified so that the cart "catches" a string connected to a wheel immersed in a tank. After the cart "catches" the string, the wheel is forced to turn as the string is spooled out. This transfers energy to the wheel. Students then calculate the amount of energy transferred to the wheel and compare it to the moment of inertia and mass of the wheel. Finally, the tank is filled with water or other fluid, and the experiment is repeated. By comparing the amount and rate of energy lost by the cart for "no catch," catching the wheel, and catching the wheel in various viscosity fluids, students gain an understanding of how viscosity affects the rate of energy transfer. The use of different size or shaped wheels (diameter, thickness, size of baffles, and the number of baffles) allows evaluation of the effects of turbulence and moment of inertia on the system.

In contrast, the UV Irradiation and Shielding module is focused on chemistry and physical science concepts. The module is motivated by the need for effective shielding from various sources of radiation, including UV-protection for sailors working outdoors. The activity developed uses simple materials, including UV activated beads, a UV lamp, and sunglasses and shields with and without UV-protective coatings. In the activity, students place the beads under UV light for a fixed period. Students then test lenses from sunglasses and car window tinting. They repeat the experiment several times using different "screens" each time. They then rate the performance of each screen and relate it to material properties such as polarizing sunglasses and the active ingredient in the sunscreen. The module explores the concepts of the electromagnetic spectrum, shielding, and the absorbance of different wavelengths by different materials.

The Alternative Power for Ships module focuses on the development of engineering design skills. This module is intended for engineering focused Project Lead the Way courses. The Navy's goal of developing alternative fuel sources to mitigate the impact the Navy's activities has on global warming was the motivation for this activity and topic. The activity developed focuses on the design and racing of solar powered "boats." Fuel cells, solar panels, batteries, electric motors, etc. are supplied and students design and build a small powered vessel. To generate excitement, a competition was included. Students raced their boats to determine whose design was fastest.

Conclusions

To date, the developed curriculum units have been utilized in five different high schools in courses, including physics, physical science, introduction to engineering, and chemistry. Student responses indicate that the hands on activities are stimulating and promote learning. After a recent presentation of the Advanced Arresting Gear unit, one student commented that he finally understood the difference between speed and velocity and that the relationship between velocity mass and energy was clearer. Teachers involved in the project have displayed a high level of ownership over the units they helped to design.

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