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Enriching Student Learning through Compelled Active Participation in a Coastal Resiliency Course

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Abstract

As the primary commissioning source for civil engineers for the U.S. Coast Guard, it is imperative that our graduates understand the projected impacts of climate change – sea level rise, altered hurricane patterns, and other associated hazards – on coastal infrastructure. At the United States Coast Guard Academy (CGA), the civil and environmental engineering faculty recognized the need to educate the future of our Service and have developed a *Coastal Resiliency* Course that incorporates climate science into engineering practice. *Coastal Resiliency* provides students an exposure to best practices in civil engineering, climate science, community planning and policy. At CGA, no one faculty member has expertise in these collective arenas however, as a team, the combined knowledge of three faculty members, and several guest lecturers, has been leveraged to annually teach a course that educates future Coast Guard Officers and civil engineers about the challenges ahead for coastal communities. What began as a team-taught course has morphed into a successful example of an egalitarian classroom where daily student participation, student lead discussions and a term project have created a classroom environment where students lead their scholastic experience. By pushing the ownership to the students - 40% of their classroom grade is based on participation - the classroom conversations have deepened, and more diverse perspectives have emerged. Students have self-reported that the benefit of these experiences will help them to better lead and serve in an increasingly complex 21st century. This paper shares the teaching approach and pedagogical tools used to promote student learning and engagement, including a history of assessment-driven changes made to the course since its inception in 2017.

Introduction

The United States Coast Guard Academy (CGA), located in New London, Connecticut, is the smallest of the United States military academies with approximately 1100 cadets. The mission of the CGA is to educate, train and develop leaders of character who are ethically, intellectually, and professionally prepared to serve their country and humanity [1]. CGA offers Bachelor of Science degrees in nine majors, including civil engineering, and all cadets are required to graduate in four years. The civil and environmental engineering curriculum is broad and provides a solid background in the structures, environmental, geotechnical, and construction sub-fields of civil engineering. Graduates pursue several different career paths and many of them serve in the United States Coast Guard (USCG) as practicing civil engineers, pursue professional licensure, and attend graduate programs in civil engineering. Emphasis is placed on balancing theory and practice of engineering, so graduates are intellectually and professionally prepared to provide engineering services to the USCG. Professional skills are reinforced in the engineering courses through laboratory reports, technical papers, presentations, design projects, field trips, interactions with practitioners and USCG officers, community outreach activities, and professional membership. Significant mentoring and advising takes place throughout a cadets' years at the CGA as an important component for intellectual development and service readiness. The approach of using every opportunity to infuse practical, industrial, and USCG relevance into course content has proven successful in fulfilling CGA's mission.

With increasing evidence of changing climatic conditions [2], such as increased atmospheric and ocean temperatures, extreme precipitation events, and global sea-level rise, predictions regarding the potential impacts on engineered systems remain in question. These challenges have positioned the civil engineering community with the task of ensuring that structures can withstand the loading imposed by these previously unaccounted for conditions. From the assessment of the resiliency of coastal infrastructure due to rising sea level to an understanding of the future impacts of forces of nature on our built environment, the importance of educating future generations of engineers with respect to coastal resiliency has become increasingly obvious. There are uncertainties in the future levels of greenhouse gases and the predictive models of future climate that make it difficult to define the statistics of future climate and weather extremes [3, 4]. The planning and design of new coastal infrastructure must consider the future climate to ensure a safe and resilient design. Therefore, it is the responsibility of not only industry, but also of academic institutions to educate students (future leaders) about the importance of mitigating the impacts of climate change and developing appropriate solutions.

In 2016, the civil and environmental engineering faculty at the CGA recognized the need to educate the future of our Service and developed a *Coastal Resiliency* course. The course provides exposure to the science of climate change, its impact on civil engineering infrastructure and on the planning and design of resilient structures. The *Coastal Resiliency* course also fosters preparation for real-world practice of engineering by exposing students to the importance of risk and vulnerability assessment within the context of changing climatic conditions. As a sea-going service, a majority of the USCG's assets are along the coastline and CGA is the primary accession point for civil engineers who provide mission support. Ensuring future engineers are exposed to the potential challenges that will likely occur due to rising sea level and other climate-related hazards is an issue of readiness and of utmost importance. While this course was initially designed for civil engineers, the course topics have attracted students from a variety of majors. The diverse mix of students from multiple disciplines has fostered and enhanced the interdisciplinary nature of the course. This paper specifically addresses the approach used by the United States Coast Guard Academy civil engineering program to incorporate climate science, engineering and policy into student focused, multi-disciplinary education. The future of our nation is better served by graduates of all academic majors that have an appreciation for the challenges that lie ahead for our coastal communities and who are exposed to solutions that promote resiliency in a changing environment.

Overview of Coastal Resiliency Elective Course

Coastal Resiliency is a 3-credit elective course in civil and environmental engineering that was first offered to 8 students in Spring 2017. It was initially designed for the civil engineering major with a heavy focus on developing civil engineering solutions. Over the past six years, the course has become more multidisciplinary to be more inclusive and encourages systems thinking. As a result, the course has become very popular and previous enrollment has surged to 31 students. For the Spring of 2023, there are 19 students enrolled in the course from five of the nine majors on campus. The course is focused on how to incorporate climate science into planning and design, using case studies to highlight best practices in infrastructure and community resilience. Emphasis on the importance of risk and vulnerability assessments of facilities and communities in dynamic environments, and compelled active participation prepare students for real-world challenges and highlights the exciting opportunities that lie ahead in their professional careers.

The course objectives are as follows:

- Provide exposure and foster general understanding of analytical methods used to update and describe climate for planning and design.
- Identify methods of assessing the impacts and vulnerabilities caused by changing climate conditions.
- Discuss best practices in climate change mitigation and infrastructure resiliency, especially practical methods to improve community resiliency.
- Discuss the Coast Guard's initiatives and approach to reducing risk and ensuring that shore assets are resilient.

Pedagogical Tools to Promote Student Learning and Engagement

The *Coastal Resiliency* course is structured to foster student focused learning by actively engaging students through research of key issues of climate science and engineering adaptation to promote the development of information literacy skills. The interdisciplinary make-up of the students and term project requirements reinforce the development of teamwork, problem-solving, and communication skills. The in-class discussions and the team-based format of the course require students to prepare to participate so as not to let their peers "down" [5]. The discussions promote independent thinking and motivation as well as enhance student involvement [5,6]. Interaction with project sponsors who are excited to work with students further generates enthusiasm and a sense of adding value to the local communities. The urgency of the issues, associated challenges, and direct connection to impacts on a community motivates and empowers students to make a difference through the engagement in lifelong learning. To make the course engaging and facilitate student learning at higher levels, several pedagogical tools are employed:

- *Compelled Active Participation* – Every student is given multiple opportunities to be actively involved in the semester-long activities. Students have individual and group work assignments in which they lead discussions and/or present to the entire class. During class discussions, the participation of each student is tracked on a spreadsheet. Students are made aware of instructors' expectations to be active learners and to lend their voices to the discussions. This has created a psychologically safe atmosphere of open dialogue in which there is a desire to participate—more than 90% of students contribute during each class. Students receive credit as part of their course grade depending on the number of times they engage in the lessons and discussions. The spreadsheet is reviewed weekly (class meets 3 times a week) and if there are students who have not participated in 2 consecutive classes, they are informed and encouraged to be more active in class or to post via the class chat to contribute to the discussions. The course was specifically designed to compel a high level of student participation to foster an active learning environment.
- *Current Event Discussions* – Instructors facilitate weekly discussions on contemporary issues in the news related to climate change, climate justice, resiliency, etc. During these sessions, either an article, news clip or video is introduced, and students are asked to comment or provide their perspectives. Instructors support an inclusive learning environment in which diversity and individual differences are understood, respected, and appreciated. All students benefit from these experiences that will help them to learn, lead, and serve in an increasingly complex 21st century workforce. Furthermore, these weekly discussions have reinforced the perspective that resiliency to climate induced changes is a

global challenge that cuts across all racial and socioeconomic boundaries. Students are also encouraged to identify and submit articles to the instructors that they want to share for discussion by the entire class.

- *Student led discussions* – There are multiple opportunities embedded in the course for students to research a topic and lead class discussions or make presentations to the class. Some examples include researching and making presentations on climate proxies, leading weekly discussions on contemporary issues, presenting on topics of their choosing related to course content, and risk and vulnerability assessments of USCG facilities and local communities.
- *Role Playing* – Students are required to work in groups of 3-4 to represent different countries (The Netherlands, India, Egypt, China, Ukraine, and Cuba) seeking international aid from the United Nations (UN) to address the goals of COP26. Students research their selected region to identify climate-related issues, develop a proposal to improve resiliency to these issues, and ensure their plan has a global impact. Students play the roles of regional representatives to the UN to present their proposal as they compete for the aid. Only one region can be awarded the aid, so the arguments and rebuttals to other nations have to be convincing to a panel of faculty who serve as UN officials.
- *Computer simulations and software packages* – There are several computer simulations that have been very useful especially for visual learners. These include simulations of climate models that predict or show how climate-related hazards impact communities. Examples are included below to highlight the resources currently being used and to create an opportunity for feedback if a reader has other suggestions:
    - *U.S. Climate Resilience Toolkit (https://toolkit.climate.gov/)*
    - *FEMA National Flood Hazard Viewer (https://www.fema.gov/flood-maps/national-flood-hazard-layer)*
    - *NOAA's Sea Level Rise Viewer (https://coast.noaa.gov/slr/)*
    - *USGS Coastal Storm Modeling System (CoSMos) (https://www.usgs.gov/centers/pcmsc/science/coastal-storm-modeling-system-cosmos)*
    - *Environmental Defense Fund – Maps of Natural Gas Leaks (https://www.edf.org/climate/methanemaps): Example provided as a resource used to highlight utility infrastructure vulnerabilities.*
- *Movies and videos* – Several movies and videos about the impact of greenhouse gases on climate and temperature, including clips from recent nightly news segments are used to demonstrate key concepts and foster discussions on the issues. Examples of movies and videos include:
    - *Shored-up*, a film by Ben Kalina, that documents the impact of Hurricane Sandy on NY/NJ, provides an overview of the U.S. Army Corps of Engineers beach replenishment policies, and highlights some socio-economic aspects of disaster relief and management.
    - *Age of Consequence*, an Emmy nominated film by P.F. Pictures, which highlights the potential impact of climate change on national security, military deployment, global unrest, and global security.

    - *Dark side of the electric car revolution*, a video which highlights how the electrification of the global transportation industry is causing a boom in cobalt mining in dangerous conditions in the Democratic Republic of the Congo.
- *Partnerships* – The content of the course was developed to foster interdisciplinary work in several disciplines including engineering, the sciences, humanities, and industry experts. Guest speakers from different backgrounds and experience are invited to share their perspectives.
- *Ethics of Climate Change* – To further reinforce the global nature of the challenges, a new module on *ethics and global nature of the challenges* was added to the most recent offering of the course. This module promotes discussion on the disparity of who is most affected by climate-induced changes and the socioeconomic impacts at a global level.
- *Case Studies* – These include the impacts of climate change on infrastructure and communities (i.e. hurricanes, drought, flooding, wildfires, etc.), global engineering solutions, ongoing research on soft and hard coastal engineering solutions, and current challenges for Coast Guard facilities.
- *Site visit* – The course includes site visits to several local communities and U.S. Coast Guard facilities. During these visits students assess vulnerabilities, risk, and interview residents to identify their understanding/concerns about how changing climate patterns may their impact communities. This aspect of the course is linked to the term project which must be completed in teams of 3 to 4 students.
- *Emphasis on practical applications and relevance to local community* – The term project is the culminating event of the course and is described in the next section. Students are encouraged to be engaged in assessing diverse perspectives on the issues including incorporating science into engineering solutions, policy, and community awareness/engagement. Their proposed solutions must be relevant and compatible with the local community they are trying to serve.

The intersection of engineering and social science where natural hazards occur has become a significant component of vulnerability assessments and the development of resilient engineering solutions for communities and federal facilities. This can be seen in the Department of Defense Climate Risk Analysis to the National Security Council [7] and various resilience master planning reports which incorporate numerous stakeholder meetings to brainstorm engineered solutions that are economically and socially viable. This sociotechnical approach has been infused throughout the course and tools noted above by the diverse group of faculty coordinators to help students understand how incorporating science, policy, global ethics, awareness, and engagement can lead to community and global solutions.

Term Project

The objectives of the term project are (1) to provide students with a hands-on opportunity to conduct a risk and vulnerability assessment of a practical real-life project, and (2) for students to apply the concepts and principles of resilience to develop appropriate solutions to climate-change-induced hazards within a given community. The deliverables of the term project include a brief report and an oral presentation. The project teams are encouraged to focus on practical applications of sustainability, scientific and engineering principles, and policies to address the challenges of infrastructure and operational resiliency within the context of changing climatic conditions. The key components encompass the assessment of the risk and vulnerabilities

involved with maintaining status quo; development of solutions to improve the resiliency; if appropriate, recommendations for further research or support for a resilient stewardship of the issues into the future. A small sample of projects is presented in Table 1.

Table 1. Sample Risk and Vulnerability Assessment Term Project

Project title	**Location**	**Narrative/Proposed Solution(s)**
Vulnerability Assessment of CGA campus	New London, CT	The waterfront facilities at the CGA may be at risk to climate-induced hazards. Conduct a risk & vulnerability assessment and develop solutions. Proposed solutions: Specific areas of concern on campus were identified including the assets effected and the risks to these assets. Solutions, including engineered solutions and best management practices, were proposed. The solutions included an assessment of vulnerability comprised of an examination of the exposure, sensitivity, and adaptive capacity of the asset.
Coastal Erosion and Burn Pan Stabilization	Mobile, AL	A research facility on Little Sand Island at the mouth of the Mobile River, AL is in danger of sinking due to erosion and deposition on the island. Research the morphology including historic changes to the island due to the climate; identify suitable instrumentation to monitor the changes, recommend potential solutions. Proposed solutions: Develop a monitoring program to better quantify the rates of erosion around the island and install oyster reefs in the vulnerable locations that are identified.
City of Groton Vulnerability Assessment & Resiliency Plan	Groton, CT	A vulnerability assessment and prioritization of critical vulnerabilities is required to support a grant proposal to develop a citywide resiliency plan. This includes utilities, vulnerable properties, and overall infrastructure. This project involved a review of the grant request for proposal and other documents identified in the literature review, engagement of City and community partners to identify critical City infrastructure, assessment of the potential impacts of climate change and extreme weather events, and development of a vulnerability assessment with the prioritization of critical vulnerabilities. Proposed solutions: Given the distinct districts within the City of Groton, the project team focused the analysis on a coastal historic district. Solutions including wet/dry floodproofing of historic facilities, elevating non-historic facilities, installing permeable pavement where practical, modifying existing drainage systems, and nourishing the community beach, were all proposed.
City of Groton Future Floodplain Limit Analysis	Groton, CT	Based upon the City of Groton's research, no mapping has been completed to understand the implications of sea level rise on the various flood plain areas. Considering the City's coastal vulnerabilities, this project determined how sea level rise would impact flood zone limits by conducting desktop surveys, field validations, a literature review of FEMA flood zone regulations and NOAA sea level rise projections, and environmental and city stakeholder interviews to develop recommendations on how different levels of sea level rise will affect the City's coastal zones in 2050 and 2075. Proposed solutions: The district most vulnerable to sea level rise in the City of Groton was identified and updated maps were developed in ArcGIS to indicate where the projected FEMA AE flood zone will be in 2050. The team also visited the district to categorize the types of home construction and identify the most vulnerable structures.
Mystic Seaport Infrastructure Resilience	Mystic, CT	Founded in 1929, Mystic Seaport is extremely vulnerable to climate change and sea level rise as documented in assessment reports and regular observations during storms and significant high tide events. This project involved a review of previous assessments for the Seaport and Mystic River along with other documents identified in the literature review, engagement with Seaport stakeholders to validate the literature review findings, identification of critical vulnerabilities, and development of resilient solutions with prioritized recommendations. Proposed solutions: Due to the historicity of the seaport, a variety of solutions were proposed including dry floodproofing of critical facilities, wet floodproofing of storage/open buildings, reconstructing/raising the unstable seawall, and improving the site drainage/stormwater management system.
Waterford/Niantic Watershed Environmental Resilience	Waterford, CT	This project involved an environmental and stormwater assessment of the potential impacts of climate change and extreme weather events on the Niantic River Watershed as a natural and economic resource, engagement with the Niantic River Watershed Committee, Nature Conservancy and other environmental stakeholders, and development of a management plan with prioritized action items to protect the natural resources of the Niantic River Watershed. Proposed solutions: Reinvigorate the existing riparian buffer by planting native species and expanding the area along the shoreline to restore the biodiversity and filter stormwater flowing into the river. In the area where development is occurring, pervious pavements and a community service outreach program were proposed to sustain the cleanliness and natural resilience of the popular area.

Assessment of Student Engagement and Learning

Since the establishment of the course in 2017, enrollment has included a diverse mix of students from different majors across CGA as shown in Figure 1. The assessment strategy used focuses on a series of student-led activities to assess the level of engagement and understanding of the concepts discussed. A summary of these activities and the associated course modules are summarized in Table 2. There are no written exams in the course as emphasis is not placed on the numeric grades, but to promote a positive and engaging experience for students. As stated earlier, the course was specifically designed to compel a high level of student participation to foster an active learning environment. Students are encouraged to be active participants in the discussions and ample opportunities are provided for students to share their perspectives and experiences. Class participation accounts for 40% of the course grade and to successfully complete the course, each group of students must complete the term project, submit a final report, and present their findings to the entire class. The participation component of the grade is determined by first normalizing to the most active student(s), i.e., the most active student(s) are assigned 1 point per class that they participated in. Many students receive 1 point per class over the course of the semester for their participation. Knowing that all students may not, at least initially, be comfortable, an acclimation period is used. To ensure that the course is run through an egalitarian lens, students who prefer to participate in a less vocal manner can submit current events for discussions or share tools they think may be useful for the term project as a way to contribute in the course.

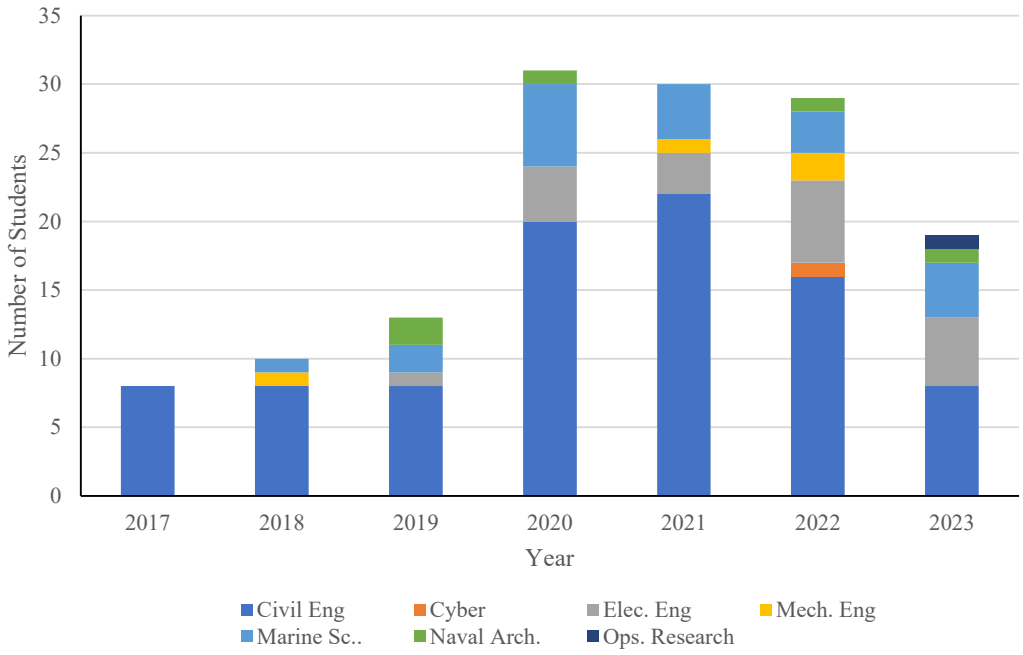

Figure 1. Summary of Student Enrollment by Major

Table 2. Summary of Course Modules, Student-led and Assessment Activities

Module	Narrative	Student led activity	Assessment Activity
Climate Science	This module focuses on the cause of climate change and the concepts of tracking climatic changes and climate modes	Students are assigned different climate proxies to research & present to class	In-class presentations & discussions, class participation
Social Impacts; ethics of climate change	This module focuses on the socioeconomic impact to underrepresented groups, global ethics of sustainability, policies	Review of news videos and articles; discussions of different local & global perspectives	Class participation
Framework for Resiliency	Definition of resilience, components of a resilient system, application to a term project	Term project and class discussions	Report & oral presentations
Vulnerability & Risk Assessment	Risk models, vulnerability assessments, impacts on global security	Term project including site visits, video, & class discussions	Report & oral presentations
Start of the Art in Developing Solutions	Global practices, case studies, solutions (approach) for existing & new facilities, interdisciplinary tools	Term project	Report & oral presentation

Course Improvements

As previously mentioned, the *Coastal Resiliency* course was first offered in 2017. Over the past seven years, several modifications have been made due to student feedback, instructor assessment of the course content, and evolution of fundamental research linking climate change to coastal resiliency. Assessment results and subsequent course changes are summarized in Table 3.

Several surveys were deployed to capture students' feedback on the course. One of the biggest lessons learned during the initial offerings of the course was the strong student desire for a site visit where students could physically see the mitigation measures or resiliency issues that are discussed. Therefore, more local and project site visits are now incorporated into the course. As presented in Table 1, students had an opportunity to work on a variety of projects focused on developing solutions to mitigate climate-induced challenges within the local communities. This was well received by students and project sponsors. Typically, some students are uncertain about how to approach a large scale, community issue that was not a straightforward engineering design. The open-ended project and absence of specific step-by-step instructions on how to proceed created some angst but created a good learning opportunity for students to hone their problem-solving skills. The instructors believe there is real growth in this discomfort and that, for the future, students will have a better understanding of how to navigate projects developed to address community challenges [8]. Additional measures taken to alleviate this angst included the inclusion of one project workday each week and interim assignments to ensure that students are making the required progress. In 2022, when asked which topic they felt most confident about, risk and vulnerability assessment, especially related to sea level rise (SLR), were among the top two as shown in Figure 2.

Table 3. Summary of Assessment and Course Improvements

Assessment Triggers	Improvement/Changes	Comments
Students indicated that the course was too heavy on climate science and on risk assessment.	Reduction of the climate science module. The objective was to provide breadth or a more general overview. Fundamentals of climate science were taught at a basic level so students from any major have a basic understanding. Risk was coupled with vulnerability assessments and two class exercises were developed.	The climate science module was initially delivered by a professor from the Science Department. This module is now facilitated the engineering faculty & student presentations. Class exercises on risk & vulnerability assessment were well received by students and this has been incorporated into the term project.
Improve student learning and restructure to make the course more appealing to students from any major.	More emphasis was placed on the general global debate of climate change stressors. A module on the global ethics of climate change that deals with the socioeconomic impacts was added. Another module that deals with climate change as a driver for world conflict and how this affects military missions and foreign policy has also been included. A variety of innovative teaching techniques such as short videos, more frequent current event discussions, hands-on team building exercises were introduced. Collaboration between three faculty members to present course materials throughout the semester.	Students also requested more exposure to resiliency policies and standards for the USCG and national/state levels. Course instructors worked with other academic majors to aggressively advertise the interdisciplinary nature of the course to other majors. This effort proved successful as students from multiple majors continue to sign up for the course. Students appreciate the different teaching styles of the instructors and indicated this enhanced their learning and help keep them engaged.
Enhance student engagement & involvement	Students were assigned different climate proxies to research and present to class. Discussions were led by student teams. Weekly current event discussions were introduced. Both students and instructors sought out topics for class discussions. Role playing that mimics the United Nations discussions on climate concerns, and implementation resiliency. Regular project progress briefs.	Students were given more short reading assignments to facilitate class discussions; most of the discussions were student led. Students worked in teams of 4 to research several countries, discussed and presented climate-related challenges, and proposed solutions in form of a UN debate. The objective was to convince a panel of UN officials to provide funding to improve resiliency and the most convincing team received the funding. There are several delivery milestones in the schedule to ensure that students are making regular progress on their project.
Provide hands-on exposure and local community relevance	Collaborated with local cities to develop term projects that identify resiliency improvements in their communities. USCG Sector and Base facilities were assessed as term projects.	Students had the opportunity to visit most of the project sites and in some cases, they were able to interact with community residents. For the USCG projects, students developed a better understanding of facility vulnerabilities and potential impacts on operations.
Provide diverse perspectives on the issues	Guest lecturers from other departments and industry professionals were a regular feature of the course.	Student comments indicate that they appreciate the diverse perspectives of the challenges presented in this course.

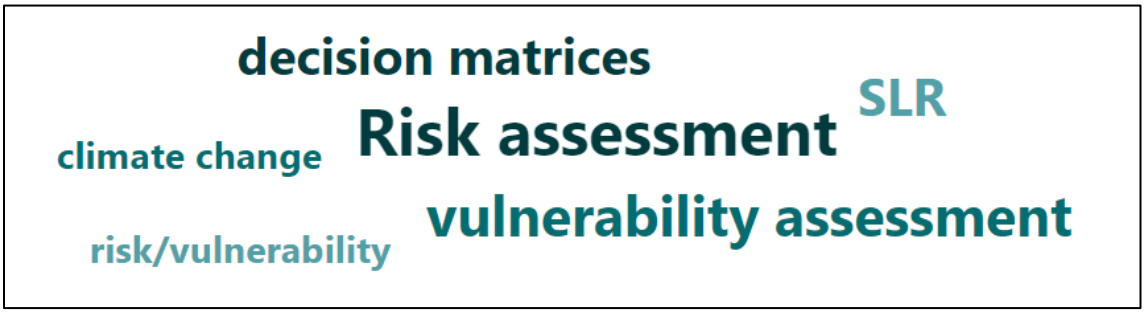

Figure 2. Word-cloud: course topics about which students feel most confident

Conclusion

The need to educate future engineers about climate-induced changes to the environment, infrastructure design, planning, and performance is becoming increasingly important. Engineering graduates must be informed of the global challenges. Academic institutions may also have to move away from the traditional way of doing things and better promote pedagogical strategies that enhance students' learning experiences. The need to educate our civil engineer workforce about infrastructure resilience to climate change requires an "all-hands on deck" approach from industry and academic institutions. Specifically, at the United States Coast Guard Academy to foster this education, an elective course, *Coastal Resiliency*, was introduced into the curriculum. This course is now open to students from any major with the objective to provide exposure to the impacts of climate change and foster a general understanding of the analytical and adaptation methods used to improve community and infrastructure resiliency. Several pedagogical tools such as videos, role-playing exercises, case studies and project-based (term project) learning are used to foster student learning of the key principles and concepts. The term project assignment provides students an opportunity to apply concepts firsthand through the completion of risk and vulnerability assessments to develop sustainable solutions that improve resiliency at USCG facilities or in local communities.

Overall course assessment focuses on providing students with a positive experience that promotes class discussions and exchange of diverse perspectives. As a result, a significant portion of the course includes student-led activities that address complex, multi-disciplinary challenges being faced by communities globally. The relevance of this course at the United States Coast Guard Academy is clear given the mission of the United States Coast Guard and the future impact climate change will have on the Service's missions. The broader impacts it has on local communities and awareness students have as future engineering leaders make it a relevant elective course for any civil engineering undergraduate curriculum.

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