Preparing Students to Solve Challenges Related to a Changing Climate

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Abstract

The National Academy of Engineering has identified restoring and improving urban infrastructure as one of the grand challenges for engineering. Urban coastal communities are particularly at risk as their infrastructure is experiencing frequent inundation related to climate change impacts. Rising sea levels in coastal communities create backflow into stormwater systems and deplete capacity. In addition, the increase in rainfall intensity, duration, and frequency related to climate change create additional challenges for aging infrastructure systems. To prepare students to solve these challenges, the Civil and Environmental Engineering (CEE) and Civil Engineering Technology (CET) programs at Old Dominion University (ODU) are introducing a new minor titled Engineering Solutions for Climate Adaptation and Resilience. This minor ensures that graduates understand how climate is changing, how it will impact society, and what solutions can be adopted to mitigate the impacts of climate change. The minor will incorporate two new classes, *Managing the Climate Crisis*, which will provide an understanding of climate science, the impacts, the associated hazards, and what solutions can be adopted to mitigate the impacts of climate change, and *Adaptation to Sea Level Rise*, which will explore solutions at the community and individual property scale to mitigate stormwater impacts related to climate change. The approach balances theory with practical engineering and technology solutions which can be adopted to mitigate the impacts of climate change related to stormwater in coastal communities. The minor is supported by existing courses in both curriculums related to sustainability, pollution prevention and green engineering, hydrology and hydraulics, and coastal engineering. This paper describes the need for the minor, the minor requirements, the methodology for establishing what coursework the minor requires, and the minor's availability to students. Furthermore, the learning objectives and course outlines for the two proposed courses that will be developed to support the minor will be thoroughly discussed. The new minor is part of a broader research, engagement, and education initiative at ODU to support adaptation and resilience for coastal communities.

Introduction

In 2017 the National Academy of Engineering identified restoring and improving urban infrastructure as one of the grand challenges of engineering (NAE, 2017). The report identified infrastructure problems related to population stress, natural disasters, accidents, and terrorist attacks that threaten infrastructure safety and security. However, missing from the list of stresses was the impact of climate change on transportation and utility systems in coastal cities. To address these challenges, the report emphasized the need for solutions that provide co-benefits, including aesthetic appeal and improved stormwater quality and quantity. The report specifically highlighted green infrastructure solutions as providing habitat creation and opportunities for human connection to nature through recreational space, as well as mitigating heat island impacts.

The National Academy of Engineering's report on engineering proceedings related to climate change emphasizes the unique role of the engineering community in addressing climate change through infrastructure transformation, mitigation and adaptation, and education. The report specifically recommends changes in engineering education to include knowledge about resilient

infrastructure and risk hazards and the need for faculty to engage students on issues related to climate change. The report discusses new industries that are being created related to climate change, including sustainable energy management, climate risk, decarbonization technology, and carbon capture, and the need to develop engineering solutions that provide co-benefits and consider equity across climate impacts and solutions (NAE, 2022).

The Batten College of Engineering and Technology (BCET) at ODU has an active record of research and education related to climate change that extends over a decade. A newly developed Engineering Solutions for Climate Adaptation and Resilience minor extends this previous work and provides students with an opportunity to understand how climate is changing, how it will impact society, and what solutions can be adopted to mitigate the impacts of climate change preparing them for practice that considers future climate.

The National Academy of Engineering's report on restoring and improving urban infrastructure as a grand challenge of engineering identified the need for solutions that address infrastructure problems related to natural disasters, accidents, and terrorist attacks. However, missing from the list of stresses was the impact of climate change on transportation and utility systems in coastal cities. To address these challenges, the report emphasized the need for solutions that provide co-benefits, including aesthetic appeal and improved stormwater quality and quantity. The report specifically highlighted green infrastructure solutions as providing habitat creation and opportunities for human connection to nature through recreational space, as well as mitigating heat island impacts.

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Building on a decade of research and education related to climate change, the BCET at ODU has developed a new minor titled Engineering Solutions for Climate Adaptation and Resilience. This minor prepares students to understand how climate is changing, how it will impact society, and what solutions can be adopted to mitigate the impacts of climate change, preparing them for practice that considers future climate. The minor will provide students with a comprehensive understanding of green infrastructure solutions and how they can address multiple challenges at once.

The Need for a Climate Adaptation and Resilience Minor

Addressing the current climate crisis will require that we mitigate carbon dioxide emissions, moving to zero carbon dioxide emissions or negative emissions and that we start adapting now to future climate scenarios. Practicing engineers need to understand why climate is changing, how it

is changing, what future environmental conditions will be, and how to incorporate future climate conditions into their designs. They need to be able to work across disciplines, with communities, and develop solutions that provide co-benefits.

Recent studies in the United States have provided evidence that climate adaptation and resilience course work is needed in civil engineering (and civil engineering technology) curricula. Shealy et al., found that while most civil engineering students believe global warming is happening (83%) only 74% believe that it is caused by humans (Shealy et al., 2021). However more than half of the students surveyed were unable to identify the causes and mitigation methods (Shealy et al., 2021). A recent study in the United Kingdom found similar results, that college engineering students lack adequate knowledge of climate change or the skills to develop solutions (Axelithioti et al., 2023).

Martin et al., (2022) highlight two challenges in their recent editorial in the Journal of Engineering Education, the need to transition to carbon-neutral or carbon-negative and the need to develop sustainable and resilient solutions to minimize the impacts to the most vulnerable populations. They argue that the first skill needed to meet the challenge of climate change is to understand how climate, sustainability, and resilience are linked in engineering design (Martin et al., 2022).

This minor will provide students with an understanding of climate science, the impacts, the associated hazards, and what solutions can be adopted to mitigate the impacts of climate change. In addition, they will explore solutions at the community and individual property scale to adapt to the changing climate. The approach balances theory with practical engineering and technology solutions which can be adopted to mitigate the impacts of climate change in coastal communities.

History of Climate Adaptation & Resilience in the ODU and the BCET

ODU launched a Climate Change and Sea Level Rise Initiative in 2010 to facilitate research and education in all aspects of climate change and sea level rise. The university has worked to create partnerships across all sectors including business, state and local government, Department of Defense, non-profits, and other groups to help Coastal Virginia prepare for sea-level rise. In addition, the institution has promoted interdisciplinary collaboration across the university to develop new curricula and foster interdisciplinary research partnerships related to climate change.

One of the academic climate adaptation and resilience efforts at ODU started with collaboration between Hampton University located in Hampton, Virginia. Initially, students from the Hampton University Department of Architecture started a project in 2014 to engage with the Norfolk community of Chesterfield Heights to research ways to alleviate existing flooding problems related to sea level rise and coastal storms. Old Dominion engineering students engaged with the effort, first as volunteers and then as capstone design students.

The project kicked off with a substantial amount of community involvement, which was managed by the civic league. As a result, students were able to identify problems related to flooding, coastal erosion, and accumulation of water in basements. Students met simultaneously with academics and area specialists with expertise including conservationists, marine biologists, landscape architects, oceanographers, and hydrologists, as well as city planners and stormwater managers.

As a result of this collaboration, students developed a set of design concepts in a preliminary engineering report involving redundant water management solutions utilizing green infrastructure alternatives and offered them to the community. The collection of solutions was modeled using the Storm Water Management Model (developed by the EPA), and the results showed that they had the potential to keep the community dry even in the face of a three feet sea level rise and a 100-year storm.

The city integrated the concept into the international design event, Dutch Dialogues Virginia. The students' design concepts were also incorporated into a grant application submitted to HUD's National Disaster Resilience Challenge, which awarded $117,000,000 in funds for execution to the Commonwealth of Virginia. The project will be completed in 2023. The project and program have received attention from media outlets and academic groups in fields beyond engineering and architecture nationally and internationally. The American Institute of Architects has identified Hampton University as one of six directing institutions for the National Resilience Initiative because of the program.

During subsequent semesters, the Coastal Community Design Collaborative (CCDC) program has been established through a memorandum of understanding between Hampton University and Old Dominion University. As part of this Collaborative, Adaptation to Sea Level Rise, an academic Concentration with ODU CEE/CET and Hampton Architecture (and some students from Hampton University Marine Sciences and Journalism) has become an official joint effort. Together, ODU and Hampton University students take two electives, in addition to an introductory course on sea level rise and shared design studio.

Since the establishment of CCDC and Chesterfield Heights community, ten (10) additional neighborhoods have been selected and studied to provide adaptive design solutions to areas inundated by flooding due to sea level rise and costal storm events.

CCDC received NSF funding from June 2018 to May 2022. "Broadening Participation Research Project: Charting a Path to Trans-disciplinary Collaborative Design" which was a three-year program to evaluate, test, and model pedagogic methods in an existing interdisciplinary (Old Dominion University engineer and engineering technology and Hampton architect) hybrid set of courses studying adaptation to sea level rise for urban neighborhoods in Norfolk, Virginia.

The current curriculum emphasizes both classroom instruction and hands-on experience in a working design studio. Students in engineering, architecture, and science programs were studied to determine what pedagogical tools, curricular support, and teaching tactics are most effective in encouraging trans-disciplinary collaboration.

The addition of the minor will strengthen the background of the students who chose to participate in the Capstone Senior Design course as part of the CCDC program. Currently students are only exposed to one course about sea level rise and climate change through CCDC however, the two newly introduced additional minor courses will enhance their engineering design knowledge about adaptive design principles to alleviate flooding due to sea level rise and coastal storm events.

Minor Requirements & Success

ODU requires that a minor support the major and expand skills related to their major, gain recognition for knowledge in another academic area, or expand job opportunities to students upon graduation. Minors are required to include a minimum of 12 credit hours of upper-division courses (300 & 400 level), which is typically four three credit hour courses (ODU Catalog, 2023). To earn a minor a student must have a minimum overall cumulative grade point average of 2.00 in all courses specified as a requirement of the minor exclusive of any pre-requisite course requirements.

A maximum of 6 credit hours (2 courses) of the minor may be in the major and credited toward both the major and the minor. Students are required to take a minimum of two of the minor courses at the university to award the minor.

The Engineering Solutions Minor for Climate Adaptation & Resilience will train students with an interest in developing engineering skills focused on adaptation and resilience to climate change and associated hazards. It will provide students with an understanding of the science, impacts, and strategies of climate change adaptation & resilience. The minor will require students to take two new 3 credit hour courses CET 458 Managing the Climate Crisis in Civil Engineering Technology and CEE 457/557 Adaptation to Sea Level Rise in Civil Engineering, both of which are described in detail below. The minor is supported by existing courses related to sustainability, pollution prevention and green engineering, hydrology and hydraulics, and coastal engineering in both the civil engineering technology and civil & environmental engineering curriculums. The additional minor courses are identified table below:

Course Number	**Course Name**
CEE 455	Pollution Prevention and Green Engineering
CEE 446/546	Urban Stormwater Hydrology
CEE 447/547	Groundwater Hydraulics
CEE 458	Sustainable Development
CEE 482	Introduction to Coastal Engineering
CET 332*	Water Resource Engineering
CET 420*	Hydrology and Drainage
CET 456	Resiliency and Sustainability

Table 1. Existing CEE and CET courses included in the minor.

The approach balances theory with practical engineering and technology solutions for coastal adaptation and resilience solutions in coastal communities. The minor is part of a more extensive research, engagement, and education initiative at ODU to support adaptation and resilience for coastal communities.

The success of the minor will be measured through a combination of student performance and post-graduation career paths, as well as through engagement with community partners to assess

the impact of students' work on coastal resilience. Ongoing assessment and evaluation of the minor's outcomes will ensure that it continues to meet the needs of both students and communities.

New Course Additions for the Minor

a. Managing the Climate Crisis

i. Description - Managing the Climate Crisis is a course that provides a structured framework for developing resilience and focuses on addressing the impacts of the climate crisis. The course aims to help students understand the risks of climate change, such as flooding, extreme heat, scarcity of water, and wildfires, and the need for immediate action. The course covers topics like hard engineering structures, nature-based design, and hybrid solutions to protect communities and create a resilient design future. Students will learn about the threats to US coasts posed by flooding caused by sea-level rise, storm surges, extreme storm events, and river flooding, as well as strategies for managing coastal flooding now and in the future. Throughout the course, students will explore new design and planning models, adaptation strategies, and budgets necessary to manage the climate crisis. The course also aims to increase student awareness of the various career opportunities in climate change, sustainability, and resilience. The course is an excellent opportunity for students to comprehensively understand the challenges posed by the climate crisis and contribute to solving them. Through this course, students can build a foundation for a career in sustainability and resilience.

ii. Objectives:

Upon completion of this course the student will demonstrate knowledge of the following objectives:

a) Comprehend the climate crisis, including the dangers of flooding, extreme heat, water scarcity, wildfires, and food shortages. They will also understand how global warming leads to climate threats such as cyclones, storm surges, heavy precipitation, heat waves, and drought.

b) Acquire knowledge about the risks to all US coasts brought about by flooding caused by sea level rise, storm surges, extreme storm events, and river flooding. They will also learn about various strategies for managing coastal flooding both in the present and in the future, including hard and soft infrastructure solutions.

c) Recognize the significance of addressing extreme heat, fresh water and food shortages, and fire hazards within the context of climate change. They will understand the challenges posed by these issues and identify potential solutions.

d) Acknowledge that climate change necessitates new design and planning models, adaptation strategies, and budgets that incorporate coastal flood protection measures for vulnerable cities and suburbs. They will be able to identify the essential factors to consider when designing and implementing climate adaptation measures and understand the roles of various stakeholders in this process.

e) Familiarize themselves with various career paths related to climate change, sustainability, and resilience. They will understand the different skill sets required for each of these roles and identify potential career paths that align with their interests and goals.

iii. Outline

This course will include the following topics in a regular semester:

- Week 1: The Climate Crisis: A National Security Problem: Understanding the climate crisis, including the dangers of flooding, extreme heat, water scarcity, wildfires, food supply, and the need for immediate action.
- Week 2: The Causes and Dangers of a Warming Climate: How warming causes climate threats like cyclones, storm surges, heavy precipitation, heat waves, and drought, and how long it will take before the climate crisis becomes unmanageable.
- Week 3: Flooding from Sea Level Rise and Storm Surges: The threat to all US coasts, as well as strategies for managing coastal flooding now and in the future.
- Week 4: Flooding along Rivers: Understanding how to manage dam and levee flooding.
- Week 5: Flooding from Extreme Storm Events: Flooding situations in specific locations and how they have been addressed.
- Week 6: Life-Threatening Heat**:** Managing extreme heat outdoors, as well as cooling designs for streets, public spaces, and buildings.
- Week 7: Shortages of Fresh Water: Understanding current water use in the United States and how to conserve fresh water in construction, landscape maintenance, and power generation. Managing water scarcity in various locations
- Week 8: Midterm Exam
- Week 9: Wildfire: Managing wildlands to reduce fire risks and making buildings more resilient to wildfire.
- Week 10: Food Shortages: Maintaining and improving farm productivity.
- Week 11: Recent Progress in Managing Climate Threats: Understanding the role of the federal government, states, and localities in implementing climate goals and plans.
- Week 12: Costs and Benefits of Managing Climate Threats: Understanding the costs of coastal flood protection for vulnerable cities and suburbs.

- Week 13: How managing the Climate Crisis can transform the Unites States: Recognizing that a changing climate necessitates new design and planning models, adaptation strategies, and budgets.
- Week 14: Careers: Increasing student awareness of various career opportunities in the field of climate change, sustainability, and resilience.
- Week 15: Final Exam

b. Adaptation to Sea Level Rise

i. Description - Rising sea levels heighten the danger and severity of storm surges and flooding in coastal locations. This is having a wide-ranging influence on our neighborhoods, as well as our community's infrastructure and economy. This course investigates the complex relationship between humans and coastlines and study how humans adapt and develop adaptation measures and solutions to tackle flooding caused by rising sea levels and subsequent coastal storm events. This course will also evaluate natural and nature-based systems, engineered systems, floodproofing methods, impacts of sea level rise on coastal water quality and on the potential impacts on disease transmission. In addition, threats to both groundwater and surface water sources will be examined due to saltwater intrusion caused by rising sea levels.

ii. Objectives:

Upon completion of this course the student will demonstrate knowledge of the following objectives:

- Describe the expected consequences of climate change and subsequent seal level rise and the role of adaptation.
- Describe and discuss the impacts of sea level rise on various infrastructure and communities.
- Learn and apply sea level rise adaptation design principles to communities and areas inundated with flooding.
- Understand the impacts of sea level rise on coastal water quality and on the potential impacts on disease transmission.
- Provide mitigation strategies to sea level rise and threats to flooding and propose actions in key sectors.
- Identify threats to surface and groundwater sources because of saltwater intrusion due to sea level rise.

iii. Outline

This course will include the following topics in a regular semester:

- Week 1: Introduction to climate change and sea level rise; the science behind sea level rise
- Week 2: Future predictions and major coastal land feature considerations
- Week 3: Flooding from sea level rise and storm surges
- Week 4: Coastal protection and mitigation strategies to sea level rise
- Week 5: Coastal protection using hard structures and soft structures to sea level rise.
- Week 6: Coastal protection using hard structures and soft structures to sea level rise.
- Week 7: Storage strategies - green infrastructure and LID strategies to manage flooding; floodproofing methods.
- Week 8: Midterm Exam
- Week 9: Managed retreat strategies and examples; Alternate approaches to coastal hazard mitigation, examples of relocating coastal communities.
- Week 10: Alternate approaches to coastal hazard mitigation, examples of relocating coastal communities: Framing policy approaches related to sea level rise; considerations among adaptation approaches.
- Week 11: Strategies for building coastal resilience and planning for sea level rise; Adaptation and examples of adaptation planning.
- Week 12: Impacts of sea level rise on coastal water quality and on the potential threats of industrial pollution and effects on public health and disease transmission.
- Week 13: Sea level rise and flooding and threats of saltwater intrusion to surface and groundwater sources.
- Week 14: Costs and benefits of adaptation strategies for sea level rise.
- Week 15: Final Exam

Impact of the Minor

a. Potential impacts on students and faculty

The impact of the Engineering Solutions for Climate Adaptation and Resilience minor extends beyond preparing students for careers and supporting vulnerable communities. The minor also has the potential to inspire and engage faculty and students in research and engagement related to climate change and resilience.

Faculty members who teach courses related to the minor may be encouraged to conduct research related to climate change adaptation and resilience. This research can lead to new insights and approaches that can be incorporated into the minor's curriculum and shared with the broader engineering community. Additionally, faculty members may develop partnerships with industry, government, and community organizations to address the challenges of climate change and improve infrastructure and community resilience.

The minor can also impact students by engaging them in research and engagement activities related to climate change and resilience. By incorporating research and engagement opportunities,

students can develop a deeper understanding of the challenges posed by climate change and the opportunities to create solutions. This can inspire students to pursue careers and further research in climate change adaptation and resilience.

The impact of the minor on students and faculty can extend beyond ODU. Graduates with a minor in Engineering Solutions for Climate Adaptation and Resilience can go on to work in engineering and related fields, taking with them the knowledge and skills developed in the minor. Additionally, faculty members engaged in climate change adaptation and resilience research can share their insights and findings with colleagues and the wider engineering community, potentially leading to new approaches and solutions.

b. Expansion of the Minor to other Colleges

Expanding the minor to other colleges at the university has the potential to broaden the reach and impact of the program. This expansion can encourage students in other colleges to pursue climate change adaptation and resilience studies, leading to a more diverse and skilled workforce. Moreover, the collaboration between students and faculty members from different colleges can foster more comprehensive and innovative solutions for addressing climate change challenges. Additionally, expanding the minor to other colleges can contribute to the university's reputation as a climate change adaptation and resilience leader. This can attract more students and faculty members who are passionate about these issues and encourage them to join the university community. This, in turn, can lead to more research and engagement activities related to climate change adaptation and resilience, further contributing to the university's impact in this area.

Summary

The National Academy of Engineering has identified restoring and improving urban infrastructure as a grand challenge for engineering, with climate change impacts posing significant threats to urban coastal communities. The worldwide increase of sea levels combined with changing local conditions, including changing weather and precipitation patterns, land subsidence, post glacial rebound and variations in ocean currents are threatening coastal communities that are at the forefront of creating adaptation solutions. Flooding threatens the communities, streets, and properties in coastal Virginia and the factors mentioned earlier combine to make flooding more likely in this area. These changes will have a substantial impact on the design and construction of infrastructure and civil engineers play a crucial role in assisting the global community to adjust to these new conditions (Reid, 2021).

To address these issues, the Civil and Environmental Engineering and Civil Engineering Technology programs at ODU are introducing a new minor titled "Engineering Solutions for Climate Adaptation and Resilience". The minor aims to educate students on climate change, its impacts, and solutions to mitigate those impacts, with a particular focus on stormwater impacts in coastal communities. The minor will incorporate theory with practical engineering and technology solutions, building on existing courses related to sustainability, pollution prevention, hydrology and hydraulics, and coastal engineering.

This initiative is part of a broader research, engagement, and education effort at the university to support adaptation and resilience for coastal communities. The university has a history of engagement in climate adaptation and resilience, with collaborative efforts with other institutions and the local community. The university's Coastal Community Design Collaborative program and Adaptation to Sea Level Rise concentration provide students with classroom instruction and hands-on experience in a working design studio to develop comprehensive flood-proofing interventions for neighborhoods affected by sea level rise and heavy storm events.

The university has also received funding from the National Science Foundation to evaluate, test, and model pedagogic methods to encourage trans-disciplinary collaboration in addressing climate adaptation and resilience. Overall, the Engineering Solutions for Climate Adaptation and Resilience minor, along with the broader efforts at the university, demonstrate the critical role of engineering education and interdisciplinary collaboration in addressing the challenges posed by climate change to urban infrastructure and coastal communities.