# Department of Ocean & Earth Sciences

406 Oceanography and Physics Building
Norfolk, VA 23529
757-683-4285
www.odu.edu/oes

Kevin Yeager, Chair
Richard Zimmerman, Graduate Program Director

Our integrated curriculum uses active learning by promoting research and education. It is designed to give graduates the skill sets to prepare them for a range of careers in academia, and the public and private sectors. The graduate program in OES draws from the strength of our diverse faculty and their active research programs that span the globe. Graduate students have the opportunity to take part in research projects among a broad suite of field sites from the local waters of the Chesapeake Bay to the polar regions.

## Programs

### Doctor of Philosophy Program

- Oceanography (PhD) (http://catalog.odu.edu/graduate/sciences/ocean-earth-sciences/oceanography-phd/)

### Master of Science Program

- Ocean and Earth Sciences (MS) (http://catalog.odu.edu/graduate/sciences/ocean-earth-sciences/ocean-earth-sciences-ms/)

### Certificate Program

- Spatial Analysis of Coastal Environments Certificate (http://catalog.odu.edu/graduate/sciences/ocean-earth-sciences/spatial-analysis-coastal-environments-certificate/)

## Courses

### Ocean and Earth Sciences (OEAS)

**OEAS 502 Field Experiences in Oceanography for Teachers (3 Credit Hours)**
Field and laboratory experiences in oceanography including hands-on experience using equipment and methods suitable for middle and secondary education professionals. Course will provide understanding of oceanic processes using simple field and laboratory experiments. Not available for credit for OES majors and minors.
**Prerequisites:** background in K-12 Education

**OEAS 503 Aquatic Pollution (3 Credit Hours)**
This course will present basic ecological principles relevant to water pollution and ecotoxicology. Topics will include runoff, eutrophication, water and sewage treatment, industrial waste, oil pollution, pesticides, and plastics in the sea. Case studies provide focal points for consideration of issues in making decisions and setting policy. This is a writing intensive course.

**OEAS 505 Physical Oceanography (3 Credit Hours)**
Physics of the ocean: properties of seawater and their distribution; water mass formation; mass and energy flows; waves; tides; models; estuarine and coastal processes. An elective for science and engineering majors.
**Prerequisites:** C or better in MATH 211 and either PHYS 232N or two semesters of hydraulics

**OEAS 506 Matlab (1 Credit Hour)**
This course is designed to introduce students to Matlab programming and to develop skills utilizing this program for data analysis.
**Prerequisites:** Junior standing or permission of instructor

**OEAS 510 Chemical Oceanography (3 Credit Hours)**
Chemical composition of the ocean and the chemical, biological, geological and physical processes controlling it.

**OEAS 512 Global Environmental Change (3 Credit Hours)**
An examination of the development of the earth as a habitable planet, from its origin to human impacts on global biogeochemical cycles on land, and in the oceans and atmosphere.

**OEAS 513 Environmental Geochemistry (3 Credit Hours)**
This course examines geochemical processes at and near the Earth's surface, focusing on the concentration, speciation and reactivity of elements in soils, waters, sediments and the atmosphere. The course examines both the thermodynamic and kinetic controls on these processes, and the role of biology as a mediator (or facilitator) of these processes. Anthropogenic impacts on natural geochemical processes are also examined.

**OEAS 515 Waves and Tides (3 Credit Hours)**
Causes, nature, measurement and analysis of water waves and tides. Mathematical and graphical application to wave and tide problems.
**Prerequisites:** C or better in MATH 212 and PHYS 232N or permission of the instructor

**OEAS 516 Electronics and Oceanographic Instrumentation (3 Credit Hours)**
The course will consist of brief lectures and hands-on laboratory exercises, in which students will learn to build, use, and debug electronic devices relevant to ocean and earth science applications. Topics covered will include circuit theory, power supplies and budgets, transducers and amplifiers, computerized data acquisition, instrument control, signal conditioning and resolution.

**OEAS 518 Limnology: Biogeochemistry of Lakes (3 Credit Hours)**
Chemical cycling in lakes and reservoirs, and interactions with biological and physical processes; quantitative modeling of lake geochemistry.

**OEAS 519 Spatial Analysis of Coastal Environments (3 Credit Hours)**
The course integrates remotely sensed and field techniques for scientific investigation and practical management of coastal environmental systems. Spatial modeling of coastal processes and management tools using geographic information system (GIS).
**Prerequisites:** GEOG 300, GEOG 402 or GEOG 502, or permission of instructor

**OEAS 520 Hydrogeology (3 Credit Hours)**
Topics covered will include the occurrence and movement of surface and subsurface water, the nature and distribution of permeable rocks and strata, field techniques used in ground-water studies, and the flow of ground-water to wells.

**OEAS 526 Concepts in Oceanography for Teachers (3 Credit Hours)**
This web-based course will provide a practical introduction to oceanography for earth science teachers. It is particularly aimed at current science teachers attempting to become certified in earth science education. Topics will include discussions of geological, biological, physical and chemical oceanography. Not available for credit for OES majors and minors.

**OEAS 530 Introduction to Geophysics (3 Credit Hours)**
Introduction to the physics of the earth, including plate tectonics, volcanism, earthquakes and seismology, gravity, the earth's magnetic field, geophysical remote sensing, and mantle convection.

**OEAS 534 Geodynamics (3 Credit Hours)**
A qualitative and quantitative description of physical processes in the Earth and environmental sciences. Topics include stress and strain, plate elasticity and flexure, heat flow, fluid mechanics, material rheology, and groundwater flow. Emphasis will be placed on developing an understanding of Earth dynamics using real-world examples, including numerical exercises.
**Prerequisites:** MATH 211, MATH 212, PHYS 231N, and PHYS 232N or equivalents

**OEAS 540 Biological Oceanography (4 Credit Hours)**
Marine organisms and their relationship to physical and chemical processes in the ocean. Laboratory study of local marine organisms, marine ecosystem and sampling techniques. Includes identification, data analysis and field trips.

**OEAS 551 Data Collection and Analysis in Oceanography (4 Credit Hours)**
This course introduces students to the basic oceanographic instruments used to obtain and analyze information by investigating different locations in the Chesapeake Bay. Data obtained with these instruments will be processed and analyzed using the data analysis techniques discussed in class. The data will then be used to answer a particular question related to the temporal and spatial variability in a natural system.
**Prerequisites:** College level statistics (at least one semester)

**OEAS 553 Marine Molecular Ecology (4 Credit Hours)**
This course will explore the ecology of marine organisms using molecular techniques and data. Molecular ecology covers a wide variety of sub-disciplines, including genetics, physiology, ecology, and evolution. The course will explore basic theory in population genetics, ecology, and evolution and cover nucleic acid techniques and their applications.

**OEAS 566 Introduction to Mitigation and Adaptation (3 Credit Hours)**
Students will be introduced to the science underpinning mitigation of human-induced changes in the Earth system, including but not limited to climate change and sea level rise, and adaptation to the impacts of these changes. The course will cover the environmental hazards and the opportunities and limitations for conservation, mitigation and adaptation. Cross listed with BIOL 566.

**OEAS 567 Sustainability Leadership (3 Credit Hours)**
In this class, students will discover what makes a leader for sustainability. They will consider a range of global and local crises from a leadership point of view in the context of sustainability science, which addresses the development of communities in a rapidly changing social, economic, and environmental system-of-systems environment. The course will be based on taking a problem-motivated and solution-focused approach to the challenges considered. The course includes a service learning project focusing on a leadership experience in solving a real-world environmental problem.
**Prerequisites:** BIOL 566 or OEAS 566

**OEAS 570 Proxy Reconstruction of Late Cenozoic Climate: Calibrations and Applications (3 Credit Hours)**
This course will examine recent developments in paleo-proxy calibration and their application in reconstructing Late Cenozoic climate history. Students will read several papers covering the theoretical basis and empirical evidence supporting some of the most common proxies used in paleoclimatology/ paleoceanography each week. Each week will begin with a lecture on the topic, followed by an in-depth discussion. Students will be required to present two of the weekly topics and lead the class discussion.

**OEAS 595 Special Topics (1-4 Credit Hours)**
Lectures, field and laboratory studies. An investigation of a selected problem in physical, geological, chemical, or biological oceanography.
**Prerequisites:** permission of the instructor

**OEAS 603 Geobiology (3 Credit Hours)**
Geobiology and the associated field of biosedimentology reflect the interdisciplinary approach to environmental problems, questions related to Earth history, and the exploration of extraterrestrial worlds. The course elaborates our understanding of geobiology and biosedimentology by conducting a study on benthic cyanobacteria and their influences on sedimentary processes in marine environments. Study area is Fisherman's Island, located close to Norfolk, VA. The course includes aspects of astrobiology (the "sister of geobiology"), and discusses the evolution of life on Earth.

**OEAS 604 Introduction to Physical Oceanography (3 Credit Hours)**
Introduction to descriptive and dynamical physical oceanography. Properties of sea water; distribution of temperature, salinity and density; water, salt, and heat budgets; techniques for describing the ocean; circulation and water masses of the world's oceans and coastal waters.

**OEAS 605 Introduction to Ocean Modeling and Prediction (3 Credit Hours)**
Instructor approval required. Introduction to concepts and theories of numerical ocean models and their applications in physical oceanography, computational fluid dynamics, environmental problems and ocean forecast systems.
**Prerequisites:** OEAS 505 or OEAS 604

**OEAS 606 Experimental Procedures in Physical Oceanography (3 Credit Hours)**
Provides basic knowledge for conducting field experiments in physical oceanography. Fundamentals of experimental design and sampling theory. Standard methods of data reduction, analysis, and reporting.

**OEAS 607 Introduction to Python for Data Analysis (1 Credit Hour)**
The goal of this class is to introduce students to the Python programming language, and to equip them with basic coding, data management and version control skills that will allow them to get more research done in less time and with less pain (computationally-speaking).

**OEAS 610 Advanced Chemical Oceanography (3 Credit Hours)**
Chemical properties of seawater; chemical composition of the ocean including major and trace elements, dissolved gases, micronutrient elements, and organic compounds; processes controlling this composition.

**OEAS 611 Chemical Oceanography Laboratory (3 Credit Hours)**
Basic analytical chemistry of seawater; field work in chemical oceanography.

**OEAS 613 Geochemistry of Marine Sediments (3 Credit Hours)**
An introduction to the geochemistry of marine sediments, with an emphasis on nutrient (C,N,P,S) and trace element cycling in marine sediments.
**Prerequisites:** OEAS 610 and OEAS 612

**OEAS 614 Estuarine and Coastal Biogeochemical Cycles (3 Credit Hours)**
Chemical dynamics within water and sediments of estuaries, salt marshes, and the continental shelf; river-sea, air-sea, and sediment-water interactions; modeling techniques.
**Prerequisites:** OEAS 610

**OEAS 620 Advanced Geological Sciences (3 Credit Hours)**
Survey of marine and terrestrial geology and geophysics; plate tectonics and basin formation; marine sediments and sediment dynamics; marine depositional environments and depositional systems; marine stratigraphy dynamics and the formation of marine basins.

**OEAS 622 Wetland & Coastal Hydrogeology (3 Credit Hours)**
Techniques used to calculate components of water budgets and groundwater fluxes in coastal systems, including wetlands, tidal rivers, estuaries, and shelf waters. Hydrologic criteria used to delineate wetlands. Many lab exercises will require field work in local wetlands and coastal systems.

**OEAS 625 Marine Sedimentary Environments (3 Credit Hours)**
Attributes of marine sediments; main sedimentary facies zones in marine and coastal environments (deep sea, shelf, tidal flats, lagoons, barrier islands); modern depositional systems versus ancient depositional systems; reefs (brachiopoda, corals, sponges, foraminifers, etc); traces and trace fossils.
**Prerequisites:** OEAS 620

**OEAS 630 Dynamical Oceanography I (3 Credit Hours)**
Dynamics of rotating, stratified fluids, geostrophic adjustment, potential vorticity, Ekman layers, gravity waves, and large scale ocean circulation.
**Prerequisites:** OEAS 604

**OEAS 640 Advanced Biological Oceanography (4 Credit Hours)**
Marine organisms and their interactions with the physical and chemical environments of the sea; primary production, population ecology, nutrition, reproduction, and marine biogeography; related laboratory exercises.

**OEAS 651 Introduction to Physics of Estuaries (3 Credit Hours)**
This course considers the physical oceanography of estuaries. In particular, it explores how circulation and mixing in estuaries are influenced by atmospheric forcing, tidal forcing, coastal influences and bathymetric variability. Topics to be treated include classification of estuaries, typical steady dynamical balances, transport of salt and other quantities, mixing, and time-space scales of variability.
**Prerequisites:** OEAS 604

**OEAS 658 Participatory and Agent-Based Modeling, Simulation, and Visualization (3 Credit Hours)**
Many societal challenges are “wicked problems,” i.e., social or cultural problems that are difficult or impossible to solve. The class will introduce the students to the theory of wicked problems, engage them in transdisciplinary approaches to address such problems using collaborative strategies such as participatory modeling combined with conceptual and agent-based models. Scenario-based simulations and visualizations will be used to explore possible futures and to create foresight related to wicked problems.
**Prerequisites:** OEAS 566/BIOL 566 or permission of the instructors

**OEAS 667 Cooperative Education (1-3 Credit Hours)**
Available for pass/fail grading only. May be repeated for credit. Student participation for credit based on the academic relevance of the work experience, criteria, and evaluative procedures as formally determined by the department prior to the semester in which the work experience is to take place.
**Prerequisites:** Approval by department is required; Additional support may be provided by the Monarch Internship and Co-Op Office in the semester prior to enrollment

**OEAS 669 Internship in Oceanography (1-3 Credit Hours)**
1-3 credits.
**Prerequisites:** permission of the department

**OEAS 695 Special Topics in Oceanography (1-3 Credit Hours)**
An advanced investigation in a selected problem in physical, geological, chemical, or biological oceanography under the direction of the faculty of the Department of Ocean, Earth and Atmospheric Sciences.

**OEAS 696 Selected Topics (1-3 Credit Hours)**
An advanced investigation in a selected problem in physical, geological, chemical, or biological oceanography under the direction of the faculty of the Department of Ocean, Earth and Atmospheric Sciences.
**Prerequisites:** permission of the instructor

**OEAS 698 Research (1-9 Credit Hours)**
Any semester; hours to be arranged; variable credit. 1-9 credits per semester. M.S.-level research.

**OEAS 699 Thesis (1-9 Credit Hours)**
Any semester; hours to be arranged; variable credit. 1-9 credits per semester. M.S.-level work primarily devoted to the writing of the thesis.

**OEAS 701 Scientific Computing for Environmental Sciences (3 Credit Hours)**
This course is designed for incoming graduate students in environmental science disciplines (e.g. oceanography, geography, ecology, geology, biology, etc.) to introduce modern computing software, programming tools and best practices that are broadly applicable to carrying out research in the environmental sciences. Material covered will include an introduction to Unix, programming using commonly used open-source languages (Python and R), version control and data backup, and data visualization tools for environmental data and making maps. Students will also be introduced to high performance computing and tools for analyzing 'big data' on remote clusters. This course is not discipline specific and is designed to be accessible to any students who want to work with environmental data.

**OEAS 704 Time Series in Oceanography (3 Credit Hours)**
A study of the basic techniques used to model and analyze time series of oceanographic data. These include temporal spatial and frequency/wave number domain techniques.
**Prerequisites:** calculus

**OEAS 705 Advanced Environmental Data Science (3 Credit Hours)**
This is an advanced computational analysis course designed to introduce students to data management and analysis methods commonly used in data science applications. The data analysis portion of the course will be primarily based on machine learning methods. The course will also give an overview of a selection of scientific databases which host freely available oceanographic data and output from numerical model simulations. This course is not discipline specific and will be useful for any students who want to work with data efficiently and gain experience in data management, proper techniques in developing analytical pipelines and applying machine learning to their research.
**Prerequisites:** Permission of instructor

**OEAS 708 Simulation Techniques for Ocean Circulation (3 Credit Hours)**
Emphasis is on the construction of working ocean models, both vorticity-stream function and primitive equation models analyzed, mostly finite difference techniques, implicit and explicit schemes, staggered grids, discussion of ocean general circulation models.
**Prerequisites:** OEAS 730, and knowledge of a computer program language (FORTRAN preferred)

**OEAS 711 Regional Oceanography (3 Credit Hours)**
The regional oceanography of the major ocean basins, marginal seas, and coastal oceans. Seasonal and interannual variability. Heat and salt cycles.
**Prerequisites:** OEAS 604

**OEAS 730 Dynamical Oceanography II (3 Credit Hours)**
Dynamics of rotating stratified fluids. Inertial waves, equatorial dynamics, coastal dynamics, dynamic instability.

**OEAS 733 Marine Microbiology (3 Credit Hours)**
The course covers the distribution, abundance, and biogeochemical activities of microorganisms in the oceans, with emphasis on prokaryotic microbes and viruses. Symbioses with higher organisms, and applied aspects of marine microbiology, including biofouling and corrosion, invasive species, and marine biotechnology are also addressed.

**OEAS 735 Paleoclimatology (3 Credit Hours)**
This course focuses on the causes (forcings) of climate change; natural response time of the climate system; interactions and feedbacks; and the geologic record in climate change.

**OEAS 741 Fisheries Population Dynamics (4 Credit Hours)**
An introduction to the major questions in the management of marine fisheries: abundance, estimation, distribution, recruitment and optimum yield. Topics are presented within the context of fisheries management, marine productivity and population ecology, all of which shape the direction of the primary literature.

**OEAS 755 Mathematical Modeling of Marine Ecosystems (3 Credit Hours)**
This course is focused on the theory and techniques of mathematical model development for marine ecosystems. The course is designed to provide an understanding of how to parameterize interaction among components of marine food webs and interaction of food web components with physical environments.

**OEAS 764 Coastal Sedimentology (3 Credit Hours)**
Sedimentary processes in different coastal zones will be described: carbonate, evaporitic, and clastic depositional systems. We will conduct a small research project along the coast of Virginia. Field trip required.

**OEAS 765 Marine Biogeochemistry (3 Credit Hours)**
This class will focus on biologically mediated elemental cycling in aquatic systems. Assimilatory and dissimilatory biological processes involving auto- and heterotrophic organisms frequently mediate elemental cycling of these elements. Inorganic compounds and dissolved and particulate organic material will be discussed in terms of their biological reactivity and turnover times in aquatic systems and their contribution to elemental cycling on a variety of temporal and spatial scales. Also included is the issue of how community structure and function alter biogeochemical cycles.

**OEAS 770 Aquatic Photosynthesis (4 Credit Hours)**
This course examines the physics, chemistry, biology and ecology of photosynthesis by aquatic organisms. Topics include light harvesting, energy transfer, carbon metabolism and biosynthesis and their ecological consequences.

**OEAS 772 Aquatic Optics (4 Credit Hours)**
The course covers the physics of light transmission through the aquatic medium as affected by scattering and absorption, the optical properties of seawater, suspended particles of living cells, underwater vision and ocean color.

**OEAS 791 Seminar (1 Credit Hour)**
Techniques for presenting scientific data at professional meetings and seminars. Practical experience and feedback from discussions with visiting speakers.

**OEAS 795 Advanced Topics in Oceanography (1-4 Credit Hours)**
An advanced investigation of a selected problem in physical, geological, chemical, or biological oceanography under the direction of the faculty of the Department of Ocean, Earth and Atmospheric Sciences.

**OEAS 801 Scientific Computing for Environmental Sciences (3 Credit Hours)**
This course is designed for incoming graduate students in environmental science disciplines (e.g. oceanography, geography, ecology, geology, biology, etc.) to introduce modern computing software, programming tools and best practices that are broadly applicable to carrying out research in the environmental sciences. Material covered will include an introduction to Unix, programming using commonly used open-source languages (Python and R), version control and data backup, and data visualization tools for environmental data and making maps. Students will also be introduced to high performance computing and tools for analyzing 'big data' on remote clusters. This course is not discipline specific and is designed to be accessible to any students who want to work with environmental data.

**OEAS 804 Time Series in Oceanography (3 Credit Hours)**
A study of the basic techniques used to model and analyze time series of oceanographic data. These include temporal spatial and frequency/wave number domain techniques.
**Prerequisites:** calculus

**OEAS 805 Advanced Environmental Data Science (3 Credit Hours)**
This is an advanced computational analysis course designed to introduce students to data management and analysis methods commonly used in data science applications. The data analysis portion of the course will be primarily based on machine learning methods. The course will also give an overview of a selection of scientific databases which host freely available oceanographic data and output from numerical model simulations. This course is not discipline specific and will be useful for any students who want to work with data efficiently and gain experience in data management, proper techniques in developing analytical pipelines and applying machine learning to their research.
**Prerequisites:** Permission of instructor

**OEAS 808 Simulation Techniques for Ocean Circulation (3 Credit Hours)**
Emphasis is on the construction of working ocean models, both vorticity-stream function and primitive equation models analyzed, mostly finite difference techniques, implicit and explicit schemes, staggered grids, discussion of ocean general circulation models.
**Prerequisites:** OEAS 730, and knowledge of a computer program language (FORTRAN preferred)

**OEAS 811 Regional Oceanography (3 Credit Hours)**
The regional oceanography of the major ocean basins, marginal seas, and coastal oceans. Seasonal and interannual variability. Heat and salt cycles.
**Prerequisites:** OEAS 604

**OEAS 830 Dynamical Oceanography II (3 Credit Hours)**
Dynamics of rotating stratified fluids. Inertial waves, equatorial dynamics, coastal dynamics, dynamic instability.

**OEAS 833 Marine Microbiology (3 Credit Hours)**
The course covers the distribution, abundance, and biogeochemical activities of microorganisms in the oceans, with emphasis on prokaryotic microbes and viruses. Symbioses with higher organisms, and applied aspects of marine microbiology, including biofouling and corrosion, invasive species, and marine biotechnology are also addressed.

**OEAS 840 Plankton Dynamics (3 Credit Hours)**
This course emphasizes the ecology of heterotrophic plankton from bacteria to protists, from metazoan invertebrate plankton to fish larvae. Students will explore the role of plankton groups and species in the context of pelagic ecosystems. Planktonic processes are not only relevant for the ocean ecosystem but also for fisheries, aquaculture, environmental and human health, and global climate. The course consists of lectures, discussion groups on selected reading material, and laboratory demonstrations.

**OEAS 841 Fisheries Population Dynamics (4 Credit Hours)**
An introduction to the major questions in the management of marine fisheries: abundance, estimation, distribution, recruitment and optimum yield. Topics are presented within the context of fisheries management, marine productivity and population ecology, all of which shape the direction of the primary literature.

**OEAS 855 Mathematical Modeling of Marine Ecosystems (3 Credit Hours)**
This course is focused on the theory and techniques of mathematical model development for marine ecosystems. The course is designed to provide an understanding of how to parameterize interaction among components of marine food webs and interaction of food web components with physical environments.

**OEAS 864 Coastal Sedimentology (3 Credit Hours)**
Sedimentary processes in different coastal zones will be described: carbonate, evaporitic, and clastic depositional systems. We will conduct a small research project along the coast of Virginia. Field trip required.

**OEAS 865 Marine Biogeochemistry (3 Credit Hours)**
This class will focus on biologically mediated elemental cycling in aquatic systems. Assimilatory and dissimilatory biological processes involving auto- and heterotrophic organisms frequently mediate elemental cycling of these elements. Inorganic compounds and dissolved and particulate organic material will be discussed in terms of their biological reactivity and turnover times in aquatic systems and their contribution to elemental cycling on a variety of temporal and spatial scales. Also included is the issue of how community structure and function alter biogeochemical cycles.

**OEAS 870 Aquatic Photosynthesis (4 Credit Hours)**
This course examines the physics, chemistry, biology and ecology of photosynthesis by aquatic organisms. Topics include light harvesting, energy transfer, carbon metabolism and biosynthesis and their ecological consequences.

**OEAS 872 Aquatic Optics (4 Credit Hours)**
The course covers the physics of light transmission through the aquatic medium as affected by scattering and absorption, the optical properties of seawater, suspended particles of living cells, underwater vision and ocean color.

**OEAS 891 Seminar (1 Credit Hour)**
Techniques for presenting scientific data at professional meetings and seminars. Practical experience and feedback from discussions with visiting speakers.

**OEAS 895 Advanced Topics in Oceanography (1-4 Credit Hours)**
An advanced investigation of a selected problem in physical, geological, chemical, or biological oceanography under the direction of the faculty of the Department of Ocean and Earth Sciences.

**OEAS 898 Doctoral Research (1-9 Credit Hours)**
Any semester; hours to be arranged; variable credit, 1-9 credits per semester. Ph.D.-level research.

**OEAS 899 Dissertation (1-9 Credit Hours)**
Any semester; hours to be arranged; variable credit, 1-9 credits per semester.Ph.D.-level work primarily devoted to the writing of the dissertation.