SEF 531 Fundamental Principles of Earth Science
Stevens Institute of Technology

School: **Engineering and Science**

Course Title: **Fundamental Principles of Earth Science**

Program(s): Science & Engineering Foundations for Education (SEFE) – Interdisciplinary

Course #: SEF 531

Catalog Description:

This second core science course is the study of earth as a dynamical system and is a continuation of the general principles learned in the first course. Students in this course will study the earth as a complex interacting system involving the large scale flow of energy and matter. The course will be an opportunity to explore the scientific method and the use of evidence to establish scientific models to aid in the understanding of a complex system. Students will study the methods used to collect and analyze earth scale data. Content knowledge will be linked with pedagogical content knowledge and discussion of how the teachers will be able to locate, implement, and design age-appropriate materials based on these concepts for use in their own classrooms.

Course Objectives

Provides a core course for the Science & Engineering Foundations for Education Graduate Certificate Program and introduces the principle of Earth Science in the context of a system of systems interconnected through the transfer of energy. This knowledge will enable teachers to independently access real world data and apply the scientific method to develop conceptual understandings of Earth science through the development of scientific models. Teachers will be able to utilize pre-existing materials, as well as design and or modify new materials, in their own classrooms. In this way the teachers will be prepared, from both the perspective of content knowledge as well as pedagogical content knowledge, to provide a much richer understanding of science and how scientific thinking evolves over time in their classrooms for the benefit of their students.

List of Course Outcomes:

The following Course Outcomes are based on the *Understanding by Design* framework that was utilized in the re-development of this course. Each outcome is presented in a table of

Established Goals, Enduring Understandings, Transfer, and Essential Questions students should be able to answer at the conclusion of the course. The broader goals and understandings are followed by a list of specific knowledge and skill acquisitions the students will achieve during the course. The Goals, Understandings, and Knowledge and Skill Acquisitions are mapped to the 2009 New Jersey Core Curriculum Standards for Science. SEF 531 has three Established Goals and Enduring Understandings: (1) Understanding of the scientific process; (2) Understanding that Earth is comprised of interconnected systems of natural processes; and (3) Understanding that matter and energy flow through Earth systems. After SEF 531 participants will have the following:

(1) Understanding of the scientific process

Established Goal	**Transfer**
Understand that science is both a body of knowledge and an evidence-based, model-building enterprise that continually extends, refines, and revises knowledge.	Students will have an appreciation of current scientific methods and an understanding that scientific theories are continually being refined based on new findings.
Understanding	**Essential Questions**
Science makes use of measurements and observation tools to assist in categorizing, representing, and interpreting the natural and designed world to continually refine and build upon existing knowledge. Conceptual, mathematical, physical, and computational tools need to be applied when constructing and evaluating claims.	How do scientists use the scientific process to develop models to explain processes in the natural environment? How do scientists utilize observed and/or measured data to prove or refine existing theories and models?

Acquisition of Knowledge	**Acquisition of Skills**
Fundamental scientific concepts and principles and the links between them are more useful than discrete facts.	Demonstrate understanding of the interrelationships among fundamental concepts in Earth systems through the use of models.
Connections developed between fundamental concepts are used to explain, interpret, build, and refine explanations, models, and theories.	Use mathematical, physical, and computational tools to build conceptual-based models and to pose theories and use outcomes of investigations to build and refine models and explanations.
Predictions and explanations are revised based on systematic observations, accurate measurements, and structured data/evidence.	Use scientific principles and models to frame and synthesize scientific arguments and pose theories.
Mathematics and technology are used to gather, analyze, and communicate results.	Gather, evaluate, and represent evidence using scientific tools, technologies, and computational strategies.
Carefully collected evidence is used to construct and defend arguments.	Use qualitative and quantitative evidence to develop evidence-based arguments.
Scientific models and understandings of fundamental concepts and principles are refined as new evidence is considered.	Monitor one’s own thinking as understandings of scientific concepts are refined.

(2) Understanding that Earth is comprised of interconnected systems of natural processes

Established Goal	Transfer
Understand that Earth contains a number of complex dynamic inter-connected systems that transfers energy between land, sea, and air.	Students will understand that each component of the Earth system; geology, atmosphere, and ocean; are comprised of diverse but related parts that function as a complex whole.
Understanding	**Essential Questions**
Convection in the earth, ocean, and atmosphere transfers heat and drives large-scale planetary circulations. Interaction between land, air and ocean systems affect planetary circulations on a global scale over large temporal scales. The geologic history of the Earth and the theory of plate tectonics provide a framework for understanding the Earth's past and the dynamic processes within and on Earth.	What is meant by a "systems approach" to Earth science? What can an understanding of Earth's past tell us about the future? What provides the energy that drives plate tectonics? What is the difference between weather and climate? What role does the ocean play in the global climate system? How does "feedback" between discrete Earth systems alter the balance of the coupled Earth system?

Acquisition of Knowledge	Acquisition of Skills
Earth's current structure has been influenced by both sporadic and gradual events. Changes caused by earthquakes and volcanic eruptions can be observed on a human time scale, but many geological processes, such as mountain building and the shifting of continents, are observed on a geologic time scale.	Examine Earth's surface features and identify those created on a scale of human life or on a geologic time scale.
Fossils provide evidence of how life and environmental conditions have changed. The principle of Uniformitarianism makes possible the interpretation of Earth's history. The same Earth processes that occurred in the past occur today.	Evaluate the appropriateness of increasing the human population in a region (e.g., barrier islands, Pacific Northwest, Midwest United States) based on the region's history of catastrophic events, such as volcanic eruptions, earthquakes, and floods.
Relative dating uses index fossils and stratigraphic sequences to determine the sequence of geologic events.	Correlate stratigraphic columns from various locations by using index fossils and other dating techniques.
Absolute dating, using radioactive isotopes in rocks, makes it possible to determine how many years ago a given rock sample formed.	Account for the evolution of species by citing specific absolute-dating evidence of fossil samples.
Major geological events, such as earthquakes, volcanic eruptions, and mountain building, result from the motion of plates. Sea floor spreading, revealed in mapping of the Mid-Atlantic Ridge, and subduction zones are evidence for the theory of plate tectonics.	Present evidence to support arguments for the theory of plate motion.
Convection currents in the upper mantle drive plate motion. Plates are pushed apart at spreading zones and pulled down into the crust at subduction zones.	Explain the mechanisms for plate motions using earthquake data, mathematics, and conceptual models.
Evidence from lava flows and ocean-floor rocks shows that Earth's magnetic field reverses (North – South) over geologic time.	Calculate the average rate of seafloor spreading using archived geomagnetic-reversals data.
Climate is the result of long-term patterns of temperature and precipitation.	Create climatographs for various locations around Earth and categorize the climate based on the yearly patterns of temperature and precipitation.

Global patterns of atmospheric movement influence local weather.	Determine the origin of local weather by exploring national and international weather maps.

Acquisition of Knowledge	**Acquisition of Skills**
Weather (in the short term) and climate (in the long term) involve the transfer of energy and water in and out of the atmosphere.	Create a model of the hydrologic cycle that focuses on the transfer of water in and out of the atmosphere. Apply the model to different climates around the world.
Clouds and fog are made of tiny droplets of water and, at times, tiny particles of ice.	Explain how clouds form.
Circulation of water in marine environments is dependent on factors such as the composition of water masses and energy from the Sun or wind.	Illustrate global winds and surface currents through the creation of a world map of global winds and currents that explains the relationship between the two factors.
Water in the oceans holds a large amount of heat, and therefore significantly affects the global climate system.	Represent and explain, using sea surface temperature maps, how ocean currents impact the climate of coastal communities.

(3) Understanding that matter and energy flow through Earth systems

Established Goal	**Transfer**
All students will understand that physical science principles, including fundamental ideas about matter, energy, and motion, are powerful conceptual tools for making sense of phenomena in Earth systems science.	Students will understand that the Earth has a global energy balance that is being altered by anthropogenic influences.
Understanding	**Essential Questions**
Knowing the characteristics of familiar forms of energy is useful in coming to the understanding that, for the most part, the natural world can be explained and is predictable.	What causes the greenhouse effect and how is the magnitude of this effect determined? How has climate varied over the Earth's history and what causes climate change over short time-scales? How will the Earth systems respond to future changes in climate? How can we harvest natural energy sources within the Earth system to reduce future climate change?

Acquisition of Knowledge	**Acquisition of Skills**
Earth systems have internal and external sources of energy, both of which create heat.	Predict what the impact on biogeochemical systems would be if there were an increase or decrease in internal and external energy.
Energy can be transferred from one place to another. Heat energy is transferred from warmer things to colder things.	Draw and label diagrams showing several ways that energy can be transferred from one place to another.
The transfer of thermal energy by conduction, convection, and radiation can produce large-scale events such as those seen in weather.	Relate the transfer of heat from oceans and land masses to the evolution of a hurricane.
Energy is transferred from place to place. Light energy can be thought of as traveling in rays. Thermal energy travels via conduction and convection.	Model and explain current technologies used to capture solar energy for the purposes of converting it to electrical energy.

Prerequisites: Students must be part of CIESE's NSF funded PISA^2 program cohort for the initial offering of this course. Alternative prerequisites will be developed at the end of the PISA^2 program so that the courses may be offered for general use.

Cross-listing: N/A

Grading Percentages:

HW (20%)	Class work (0%)
Mid-term (0%)	Mid-term Project (15%)
Final (25%)	Final Project (25%)
Other: Online Discussion Forum (15%)	

Credits: **3 credits** Other

For Graduate Credit toward Degree or Certificate

Yes No Not for Dept. Majors Other

Only for credit by joint permission from SEF Program Committee and the Home Department (if appropriate) of the student.

Textbook(s) or References

Required:

Understanding Models in Earth and Space Science
Steven W. Gilbert and Shirley Watt Ireton
NSTA Press, ISBN: 978-0-87355-266-4

The Earth System – 3rd Edition
Lee R. Kump, James F. Kasting, and Robert G. Crane
Pearson Education, Inc., ISBN-10: 0-321-73328-2

Reference:

An Introduction to the World's Oceans – 10th Edition
Keith A. Sverdrup and E. Virginia Armbrust
McGraw-Hill Science/Engineering/Math, ISBN-13: 978-0-07-337670-7

Atmospheric Science, An Introductory Survey – 2nd Edition
John M. Wallace and Peter V. Hobb
Academic Press, ISBN-13: 978-0-12-732951-2

Mode of Delivery Class Online Modules **Other: Mixed (Class, Online)**

Program/Department Ownership: Science & Engineering Foundations for Education Program – School of Engineering & Science

Department Point of Contact and Title: **Professor Thomas Herrington, Department of Civil, Environmental and Ocean Engineering**

Date approved by individual school and/or department curriculum committee: 5/21/2010 by Graduate Program Curriculum Committee; Revised 3/2011

General: The course will be offered over a three week period via blended delivery of face-to-face classroom meetings and an online component in the order given below. The course will leverage existing materials (hands-on and curricular) developed by the Center for Innovation in Engineering and Science Education (CIESE) in the areas of Earth science, energy and systems, but at a deeper level of technical depth and rigor appropriate for a course of this nature and building upon material covered in course one (SEF 530) in the PISA^2 sequence.

- A 'pre-reading homework assignment of selected chapters of *Understanding in Earth and Space Science* prior to the first class meeting
- Initial 3 hr pre-test followed by 3 hr face-to-face-meeting (F2F Session 1) with an optional 2 hr after class support session.
- Four days of 4 hr face-to-face meetings (F2F Sessions 2 – 5) with optional after class support.
- Five Days of Online Learning Activities and Homework comprised of 4 hrs online discussion and activities, and homework assignments
- Four days of 4 hr face-to-face meetings (F2F Sessions 7 – 9) with optional after class support.
- One 3 hr Final Exam on F2F Session 10

Day	**Topic(s)**	**Reading(s)**	**Class exercises**	**HW**
1 8:30am-3:00pm	• PRETEST • Earth as a System • The use of models in Earth Systems Science	• Selected current science articles from NSF • Understanding Models in Earth and Space Sciences	• Convective Energy Demonstration & Discussion • Analysis of science models • Building science models	• Provide a Model for the Earth as a series of interconnected systems • Reading from text on Geology and Earth as a system; key questions: How old is the Earth and how did it form? What is the composition of the Solid Earth and how has it changed over time? How do fossils form? How do we find the age of fossils?
2 8:30am-1:30pm	Historic Geology of the Earth	• The Story of O_2 *Science* Vol. 322 • New Evidence supports Snowball Earth as trigger for Animal Evolution *NSF News* 10/27/10 • New Blow for Dinosaur-Killing Asteroid Theory *NSF News* 4/27/09	• Develop model from HW readings • Investigation of rock layers to determine past geologic processes • Fossil Investigation • Radiometric dating activity • Revise model from morning	• Reading from text on Geology and Earth as a system; What is plate tectonics? What evidence is there for plate tectonics? • View Select Discovery Channel Video Clips on Plate Tectonics
3 8:30am-1:30pm	Physical Geology of the Earth	• Global Seismographic Network records the Great Sumatra-Andaman Earthquake *EOS* Vol. 86 (6) 2/05 • Island Arc Debris, Avalanches and Tsunami Generation *EOS* Vol. 86 (47) 11/05 • Viscous Cycle: Quartz is key to Plate Tectonics *NSF News* 3/16/11 • Earth's Crust Melts easier than Thought *NSF News* 3/18/09	• Revise day 2 model from HW readings • Determination of Earthquake epicenter from seismograph network. • Investigation of Earthquake and Volcanic Activity through Google Earth • Revise model from morning	• Reading from text on Oceanography; key questions: Why is the ocean so salty? What is the thermohaline circulation and why is it important?

4 8:30am-1:30pm	Physical structure of the Oceans	• Researchers link ice-age climate-change records to Ocean Salinity *NSF News* 10/4/06	• Develop model from HW readings • Investigate the buoyancy of an object in fresh and salt water. • Measure difference in salt and fresh water properties. Use Google Ocean to investigate global variations in oceans • Revise model from morning	• Reading from text on Oceanography; key questions: What factors cause the ocean to circulate? What currents form as a result?
5 8:30am-1:30pm	Ocean Tides, Currents and Waves Earth Systems	• Devil in the Deep Blue Sea *Phila. Inquire* 12/05 • Scientist Studying Deep Ocean Currents for Clues to Climates *NY Times* 11/99	• Revise day 4 model from HW reading • Use global drifter and buoy data to identify ocean circulations. Plan an around the world cruise using only currents. • Revise model from morning	
Day 6 - 10	Online Learning and Independent Study			• Online Learning/Homework Assignments • Reading from text on Atmospheric sciences; key questions: How does vertical motion in the atmosphere affect weather? What causes the rain to fall?

11 8:30am-1:30pm	Physical structure of the Atmosphere	• Climate Change and Greenhouse Gasses *EOS* Vol. 80 (39) 9/99 • Forest Disturbances and North American Carbon Flux *EOS* Vol. 89 (11) 3/08	• Develop model from HW readings • Use satellite imagery and weather balloon data to identify vertical variation in temperature. Pressure and moisture. • Use surface weather station data to make a synoptic weather map for the continental US • Engineer a better weather instrument • Revise model from morning	• Reading from text on Atmospheric sciences; key questions: What causes the wind to blow? How are weather systems created and why do they move? How does the Earth's rotation affect the winds?
12 8:30am-1:30pm	Atmospheric Motions	• Increasing destructiveness of Tropical cyclones over the past 30 years *Nature* 8/05 • Scientist Link '88 Drought to Natural Cycle in Tropical Pacific *NY Times* 1/89	• Revise day 11 model from HW reading. • Utilize online weather models to identify motions in the atmosphere. • Track a hurricane and prepare a weather forecast. • Revise model from morning	• Reading from text on Earth Systems; key questions: How is the Atmosphere and Ocean coupled? How do global atmospheric circulations affect ocean circulations and vice-versa? How are geologic processes coupled to the Atmosphere and Oceans?
13 8:30am-1:30pm	Coupled Atmosphere-Ocean-Earth System	• El Nino Dynamics *Physics Today* 12/89 • Ocean-Atmosphere-Sea Ice-Snowpack Interactions in the Arctic and Global Change *EOS* Vol. 84 (36) 9/03	• Develop model from HW readings • Investigate El Nino as a coupled air-sea system. • Investigate seafloor spreading zones as a coupled geologic-sea-air system • Revise model from morning	• Reading from reference material on Fossil Fuels and Global Climate Change; key questions: How are hydrocarbons formed? How does the burning of fossil fuels increase Global temperatures? How is Global Warming related to Climate Change?

14 8:30am-1:30pm	Energy Flow and Global Changes	• Climate Change and the rise and Fall of Sea Level over ther Millennium *EOS* Vol. 79 (6) 2/98 • Climate Change and Tectonic changes on the Ocean around New Zealand *EOS* Vol. 89 (31) 7/08 • Long-term Global Heating from Energy Usage *EOS* Vol. 89 (28) 7/08	• Develop model from HW readings • Investigate paleoclimate and paleo-ocean data to deduce prior climates. • Identify natural potential and kinetic energy sources. • Engineer a device to harness natural energy • Revise model from morning	• Review for Final Exam
15 8:30am-11:30am	FINAL EXAM			