Implementing InTeGrate Critical Zone Science materials in an undergraduate geoscience curriculum

Ashlee Dere[1], Timothy White[2], Adam Wymore[3], Adam Hoffman[4], James Washburne[5], Martha Conklin[6], and Robert Shuster[1]

[1]Dept. of Geography/Geology, University of Nebraska – Omaha; [2]Earth and Environmental Systems Institute, The Pennsylvania State University; [3]Dept. of Natural Resources and the Environment, University of New Hampshire; [4]Dept. Of Natural and Applied Sciences, Dubuque University; [5]Dept. of Hydrology and Water Resources, University of Arizona; [6]School of Engineering, University of California – Merced

Assessment

Curriculum was piloted in eight courses at a range of institutions, followed by peer review and revision. Additional pre- and post-testing has been conducted in the most recent course offering at UNO in an effort to understand in more detail how CZ Science materials help to develop student learning and critical thinking skills.

Pre- and post-assessment results for all CZ pilot courses (n=30 pre and n=27 post). White et al., 2017

Question Subject	Answered Correctly (%)	
	Precourse	Postcourse
Natural hazard	96.7	88.9
Tectonic plates	60.0	70.4
Life in oceans	60.0	63.0
Human and oceans	40.0	29.6
Atmosphere and biosphere	46.7	55.6
Carbon sources	33.3	44.4
Climate modeling	93.3	92.6
Climate measurements	10.0	35.9

Pre- and post-assessment results from UNO CZ Science course (n=12, Spring 2017).

Question Subject	Answered Correctly (%)	
	Precourse	Postcourse
CZ definition and location	25	92
CZ science and grand challenges	17	75
Systems	33	88
Generating hypotheses	42	92
Environmental measurements	50	92
Environmental gradients	67	92
CZ processes	33	50
GLE – Earth Science	81	83
GLE – Atmospheric Literacy	44	47
GLE – Climate Literacy	54	79

Curriculum

Instructor Materials: Overview of the Critical Zone Science Course

Module 1 CZ Background

Module 2 Methods of Critical Zone Science

Module 3 Critical Zone Architecture and Evolution

Module 4 Land-atmosphere exchange

Module 5 Water transfer through the CZ

Module 6 Geochemistry and Biogeochemistry

Module 7 Humans in the Critical Zone

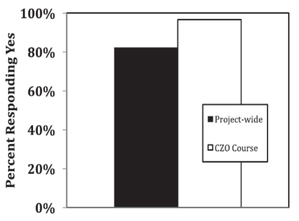
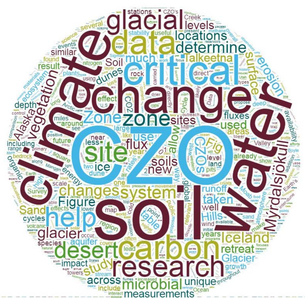


FIGURE 4: Students responding "Yes" to the question: As you think about your future, can you envision using what you have learned in this course to help society overcome problems of environmental degradation, natural resources limitations, or other environmental issues? n = 1125 for InTeGrate project-wide student responses; n = 29 for the ITCZS-course student responses. White et al., 2017

Summative Assessment: RFP from NSF: $5,000,000 to fund a new CZO. In groups of four, write a 10 page proposal that describes why NSF should fund the new CZO. Proposals are peer-reviewed following NSF guidelines and students participate in a panel review of class proposals.



Word cloud generated from all four student collaborative proposals for a new CZO.

White, T., Wymore A., Dere A., Hoffman A., Washburne J., and Conklin M. (2017) Integrated interdisciplinary science of the Critical Zone as a foundational curriculum for addressing issues of sustainability. J. Geosci. Edu. 65:136-145.

This work is supported by a National Science Foundation (NSF) collaboration between the Directorates for Education and Human Resources (EHR) and Geosciences (GEO) under grant DUE - 1125331

The InTeGrate course "Introduction to Critical Zone Science" was developed by an interdisciplinary team from a variety of institutions to introduce and examine the life-sustaining services and resources provided by Earth's terrestrial layer, the Critical Zone (CZ). The CZ extends from the top of the vegetation canopy to fresh groundwater beneath the Earth's surface and includes coupled biological, chemical and physical systems that interact to support ecosystems and humans alike. The InTeGrate curriculum uses data and literature generated from the NSF CZ Observatory program and emphasizes a systems approach to understand the nature and methods of geosciences as well as to address geoscience-related grand challenges facing society.

At the University of Nebraska – Omaha (UNO), a large, 4-year public and primarily non-residential campus, students pursuing undergraduate degrees or minors in Geology, Geography and Environmental Studies or M.A. degrees in Geography can take the course to fulfill upper-level degree requirements. The initial two course offerings each included 14 students, taught over two 75-minute sessions or one 150-minute session per week; future course offerings will include an additional 2-hour lab section.

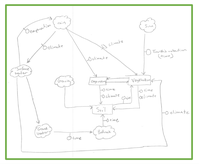
By the end of the module students will be able to:

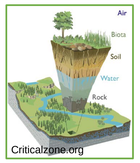
Module 1: CZ Background

Unit 1.1 - CZ Overview

Unit 1.2 - Role of Soil

Unit 1.3 - Systems Models



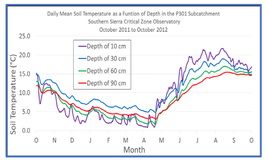


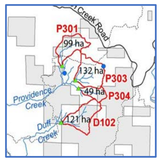
- Accurately define the CZ and the relationship to the atmosphere, biosphere, hydrosphere, lithosphere, and soil.
- Effectively summarize the transdisciplinary nature of CZ science and the relationship to system science.

Module 2: Methods in CZ Science

Unit 2.1 - Basic Tools & Analysis

Unit 2.2 - Basic Critical Zone Concepts



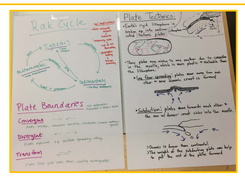


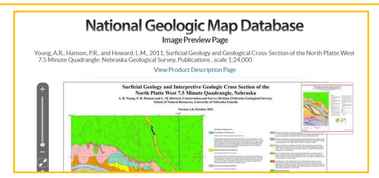
- Infer trends from multiple strands of data to answer questions about Critical Zone services.
- Summarize systems modeling and geoscientific research approaches to design a sampling program.

Module 3: Critical Zone Architecture and Evolution

Unit 3.1 - Geology and Geomorphology

Unit 3.2 - Landforms and Remote Sensing



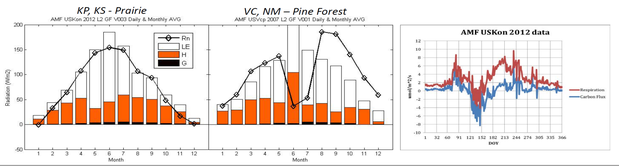


- Recognize that geology and geomorphology influence surficial processes to determine CZ architecture and evolution.
- Apply freely available online resources that provide information on geological mapping and remotely sensed imagery to site evaluation.

Module 4: Land-atmosphere exchange

Unit 4.1 - Energy Budgets

Unit 4.2 - Carbon Budgets

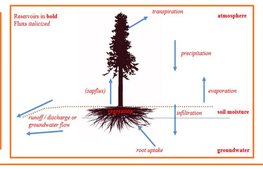


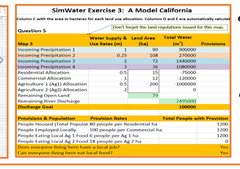
- Use CZO micro meteorological data to describe the differences between the main atmospheric fluxes at each CZO site.
- Trace primary radiative forcings through the CZ and relate carbon flux data collected at various scales to understand regional carbon exchange.

Module 5: Water transfer through the critical zone

Unit 5.1 - Water Balance of a Tree

Unit 5.2 - Water Balance Impacts



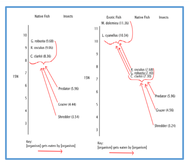


- Analyze the water budget of a catchment and calculate water budget components at multiple scales.
- Explain the reservoirs and fluxes of water cycling among the different parts of the CZ and assess anthropogenic impacts to water cycling

Module 6: Geochemistry and biogeochemistry

Unit 6.1 - Biogeochemical Modeling Framework

Unit 6.2 - Biogeochemical Examples



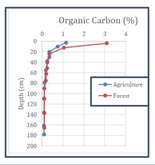
- Explain the role of CZ services in supporting terrestrial life, including humanity, and how organisms and biodiversity affect biogeochemical processes.

Module 7: Humans in the Critical Zone

Unit 7.1 - Model My Watershed

Unit 7.2 - Agricultural Impacts

Unit 7.3 - Panel Review



- Use observations, models, data analyses, and research proposals to identify and analyze anthropogenic influences on the CZ and ways to reduce human perturbations.

Field trip to the Intensively Managed Lands (IML) CZO in Eastern Iowa.