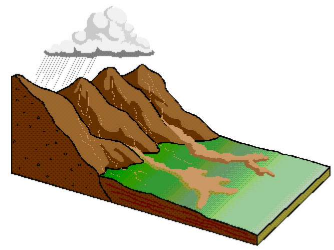
Water Sustainability in Cities: An Interdisciplinary Geoscience and Engineering Teaching Module





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[1]University of Utah, [2]North Carolina A&T,
[3]Colorado Mesa University, [4]University of Georgia

Outline

1. NSF-funded InTeGrate Project @ SERC
2. Course Module
3. Pedagogy
4. Assessment
5. Lessons Learned

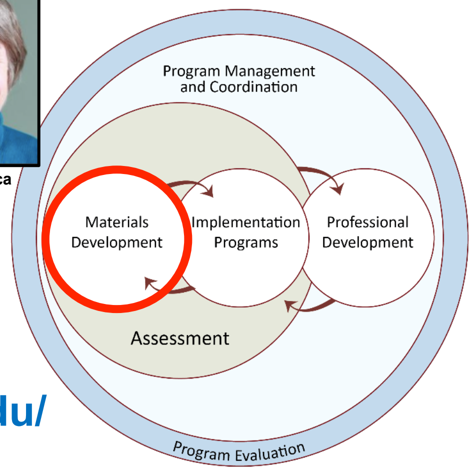
InTeGrate

Interdisciplinary Teaching about Earth for a Sustainable Future

Two goals:

- National impact on increasing students in STEM
- Address grand challenge: environmental sustainability and resource limitations

Cathy Manduca



http://serc.carleton.edu/integrate/index.html

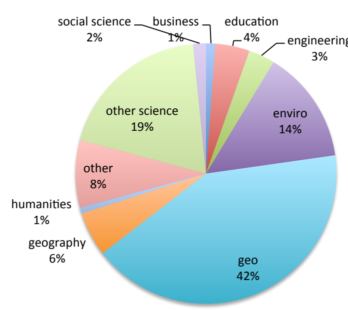
InTeGrate

Interdisciplinary Teaching about Earth for a Sustainable Future

1363 Community Members

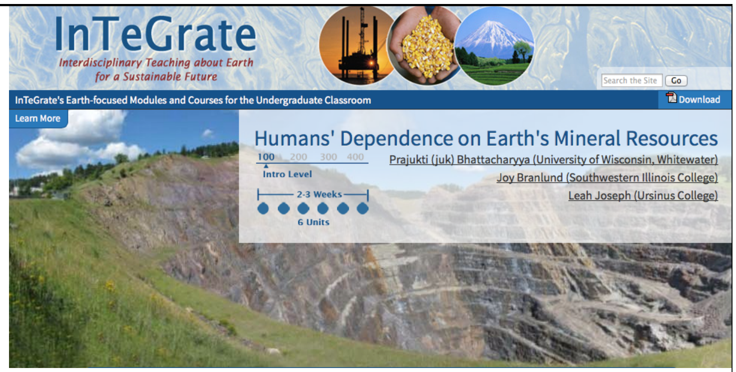
- 687 workshop participants
- 115 curricular developers
- 69 Implementation Program participants

55% female
12% under-represented minority



InTeGrate Participants by Department Discipline (n=945)

InTeGrate Curriculum Development & Revision Rubric



Guiding principles:

- Grand challenge facing society
- Interdisciplinary problem solving
- Geoscientific habits of mind
- Authentic geoscience data
- Systems thinking

Pedagogical excellence:

- Learning goals
- Assessment
- Resources & materials
- Learning strategies
- Module/course alignment

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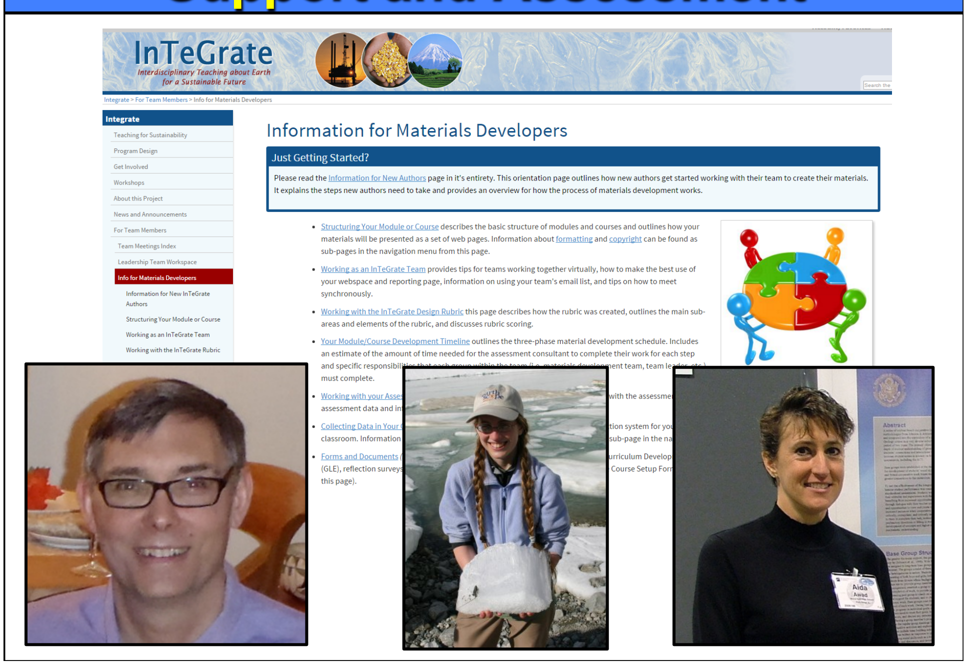
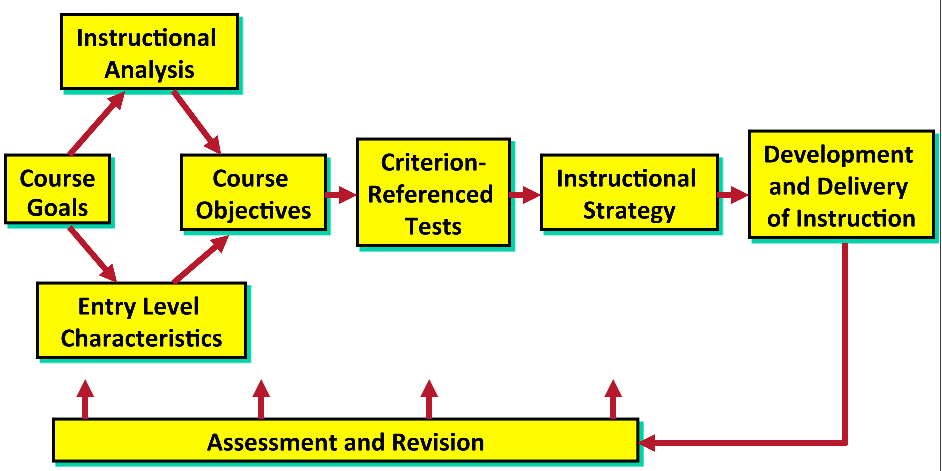
Support and Assessment

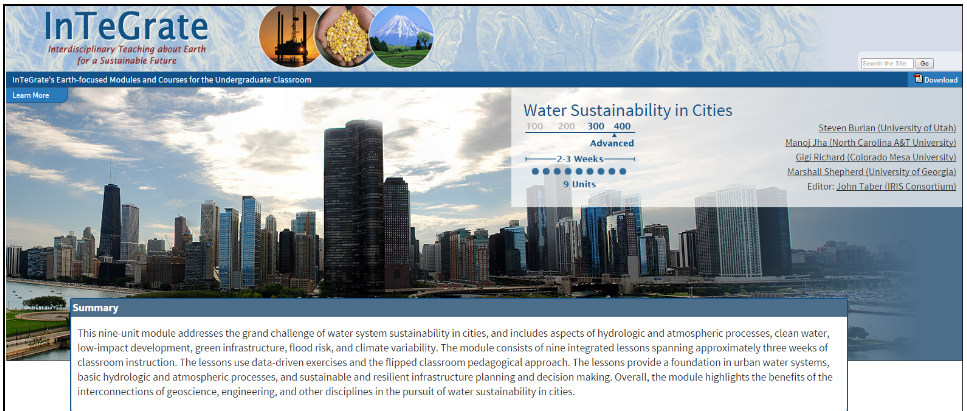


Module Strengths

- This module is designed to fuse geoscience elements of hydrologic science, atmospheric science, and biological science with sustainability concepts, systems thinking, planning, and engineering in a manner that illustrates the value of this diverse knowledge for urban water system planning.
- The varied use of flipped and traditional units with consistent use of data-enabled exercises set in place-based case study learning opportunities is also a strength. Individual and team assessments of student learning are included.
- Although designed as an integrated module, sufficient information and guidance is provided to enable instructors to incorporate individual units, activities, and components of activities into courses.
- Finally, a major strength of the module is linking the team project to the individual units to provide lesson learning exercises in the context of bigger picture and opportunities for metacognition reflecting on past material and applying it in new ways.

"Backward" Design of Instruction





Module Goal: Enhance knowledge and skills of students across disciplines to enable them to plan for water sustainability in cities

Module Learning Goals

- Explain water sustainability concepts
- Use systems thinking to enhance water sustainability in cities
- Apply knowledge and skills from atmospheric science and hydrologic science in planning and engineering water systems
- Create and evaluate alternative plans to improve sustainability of water management systems in cities

(U.S. Water Alliance)

Target Students and Courses

2-3 Weeks

9 Units

100 200 **300 400**

Advanced

A great fit for courses in:

- environmental science
- civil engineering
- geology
- geography
- water resources
- environmental geology
- earth science
- global change

Module Structure

Geoscience Foundation

- Unit 1 Module Introduction
- Unit 2 Urban Hydrology
- Unit 3 Urban Water- Atmospheric Environmental Interactions

Design

- Unit 4 Urban Landscapes and Water Use
- Unit 5 Net Zero Water Buildings
- Unit 6 Rainwater Harvesting

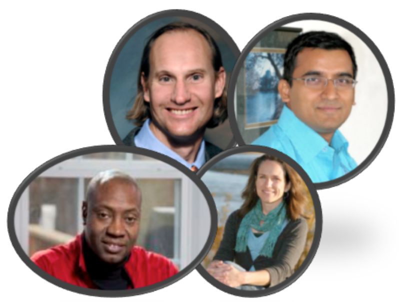
Planning and Decision Making

- Unit 7 Low Impact Development and Green Infrastructure
- Unit 8 Impacts of Extreme Hydroclimatic Events
- Unit 9 Planning and Decision-Making

Lesson Structure

Pre-Class Video	Learning Activities	Team Project
Pre-Class Assignment	Formative Assessment	Summative Assessment

Integrated Learning



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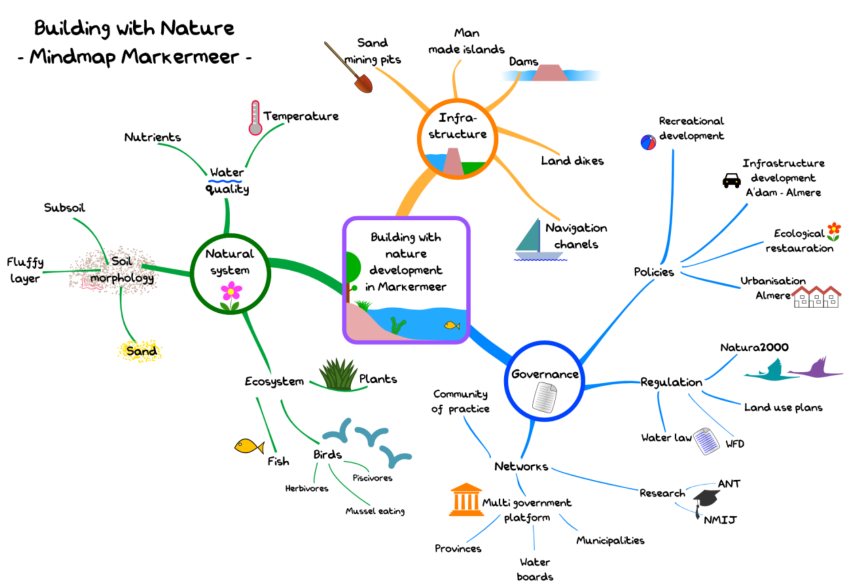
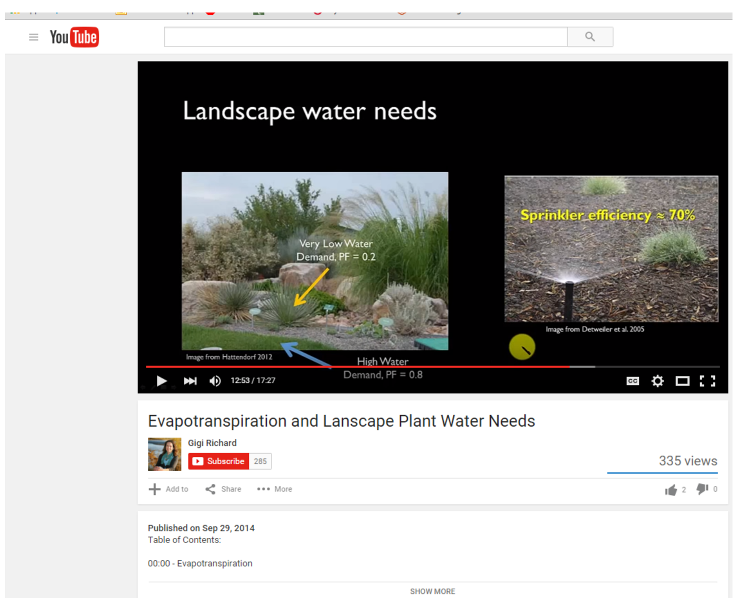
Integrated Learning



(www.ecoshape.nl)

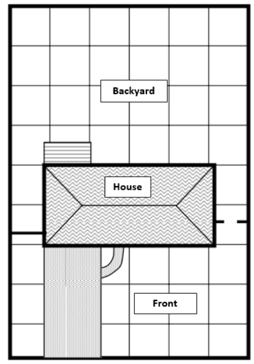
Pedagogy – Flipped Classroom



Pedagogy – Active Learning

Learning Goals

- Calculate indoor water demand of a building
- Quantify impact of conservation and technologies on indoor water demand



Activity Overview

Work in teams of 3. You will be using a spreadsheet to estimate the indoor daily water demand of the Civil and Materials Engineering (CME) Building on the University of Utah Campus, determining impact of water conversation practices on indoor water demand, and exploring the potential to achieve net zero water for the building.

Part 1. Estimate Baseline Indoor Water Use

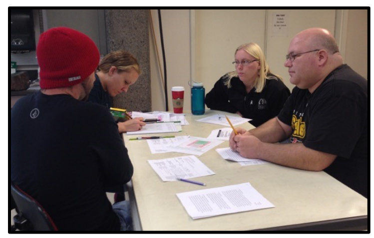
Time Limit: 10 minutes

Directions: Use the LEED Indoor Water Use Reduction Calculator spreadsheet. After the instructor provides an overview, review the spreadsheets with your team members. Ask questions to clarify points. Note that Tables 1, 2, and 4 are needed to set the baseline case and Tables 3 and 5 describe the improved design.

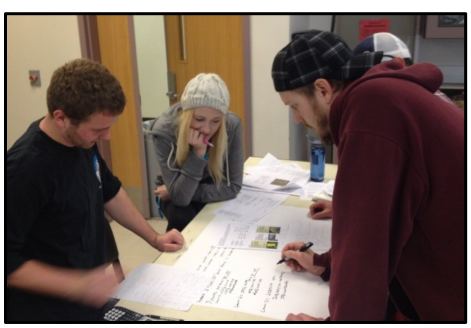
When ready or instructed to do so, enter the values as guided below (or by instructor) to estimate the “baseline” indoor water use for the CME building.

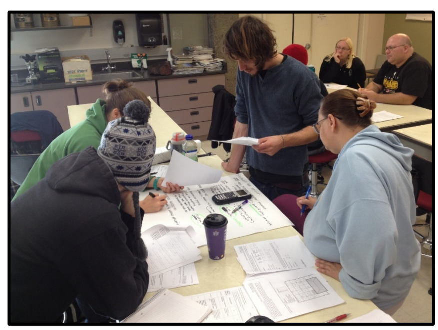
In Table 1 on the Group1 worksheet enter:

- Total Employees (FTE) = 80 (60 male, 20 female)
- Visitors = 100 (60 male, 40 female)
- Students = 30 (20 male, 10 female)



Pedagogy – Project-Based Learning





Introduction

The goal of this project is to design a 10-acre suburban development that includes up to twenty-one 2,000 ft^2 homes on 1/3-acre lots incorporating the urban water sustainability principles learned in the module. Your design must reduce both indoor and outdoor water use, reduce peak discharge and volume of stormwater runoff and pollutant loading, minimize impacts on the urban climate and increase resilience to extreme events. You will accomplish this by implementing green infrastructure (e.g., rain gardens, pervious concrete and green roofs), indoor water conservation practices, and xeric landscaping and strategizing for mitigating the urban heat island effect and making the planned development resilient to floods and droughts.

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Rubrics

Water Sustainability in Cities
Unit 9 – Final Assessment

Unit 9 - Rubric for Module Final Assessment

Unit 9 Learning Goals

Upon completion of Unit 9, students should be able to:

1. Plan a sustainable urban water system for a particular scenario
2. Articulate pros and cons of water system options
3. Conduct a triple bottom line decision analysis
4. Communicate plan via a poster presentation and short oral report illustrating decision matrix

Module Learning Goals

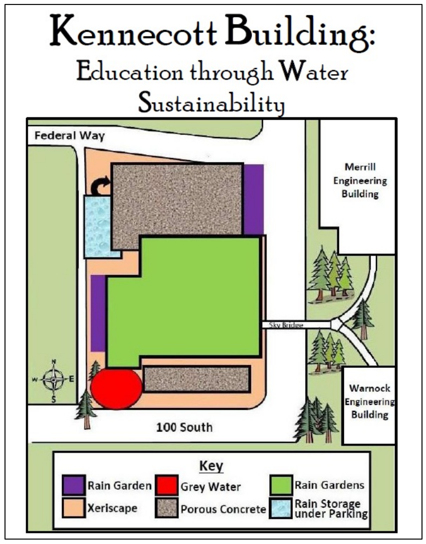
At the completion of the *Water Sustainability in Cities* module, students will be able to:

1. explain key concepts related to water sustainability
2. use systems thinking to identify opportunities to enhance water system sustainability in cities
3. apply knowledge and skills from atmospheric science and hydrologic science to plan for water sustainability in cities
4. create feasible alternatives and recommend options to improve the sustainability of water systems at building and catchment scales in cities

Unit 9 learning goal addressed	Module learning goal addressed	Review Criteria	0	1	2	3
1, 3, 4	1	**Clearly explain, using the Triple Bottom Line as a framework, why their development proposal is more sustainable than a typical development.**	Explanation does not address sustainability and no evidence of application of triple bottom line principles, or major misconceptions are present.			Clear explanation of how the triple bottom line was used to evaluate how their proposed design is more sustainable than a typical development. Includes demonstration of understanding of the concepts of sustainability and triple bottom line.
		Clear application of systems				Presentation demonstrates application of systems

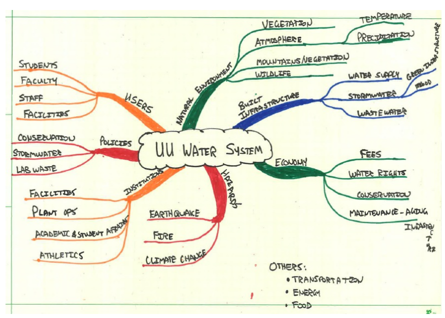
Assessment

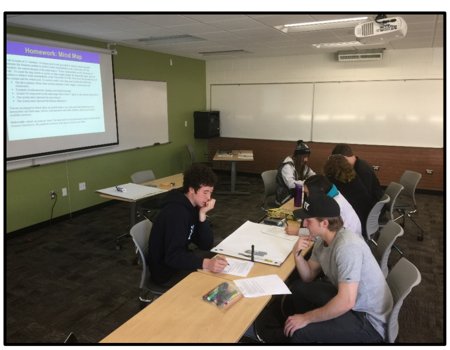
Explain water sustainability concepts

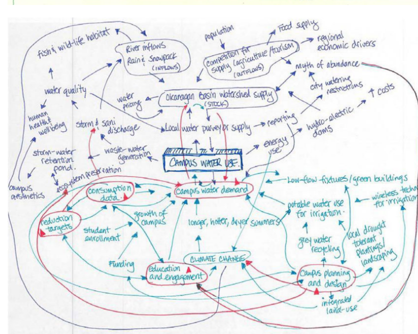


Assessment

Use systems thinking to enhance water sustainability in cities







Assessment

Apply knowledge and skills from atmospheric science and hydrologic science in planning and engineering water systems

3.3 Catchment Scale Water Management

The goal for stormwater runoff from the proposed development is to reduce the quantity of stormwater runoff, so that the developed hydrograph mimics the natural (pre-development) hydrograph. Additionally, your stormwater management plan should also consider the quality of the runoff water.

1. Use the EPA National Stormwater Calculator (Unit 7) (download here http://www2.epa.gov/water-research/national-stormwater-calculator or go to the GIS lab). Use the impervious and pervious areas given in Table 2. If you use the stormwater calculator, start with zip code 80523 and navigate to lat/long: 40.561660/-105.081895 to estimate the parameters for the model.
2. Propose strategies to reduce the developed runoff, such as green roofs, rainwater harvesting and rain gardens (Units 7).
3. Compare the natural (pre-development) runoff with your sustainably developed runoff. How does your sustainably develop runoff compare with the typical developed runoff?

3.4 Urban Climate

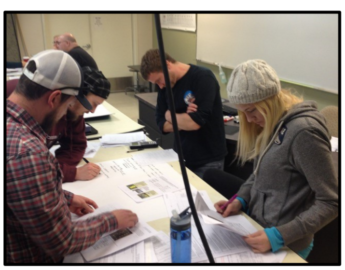
The change in albedo as a result of the construction of roads, sidewalks and homes may results in a change in the sensible heat flux of the area, which can result in a change in temperature (Unit 3). Discuss the possible impact of the proposed development on the temperature of the area and propose possible strategies to reduce these impacts.

3.5 Extreme Events

A sustainable development must also be resilient in the face of high magnitude, low frequency or extreme events such as floods and droughts (Unit 8). Consider the risk to the development from these

Assessment

Create and evaluate alternative plans to improve sustainability of water management systems in cities



Task 3. Sustainable Design

3.1 Outdoor Water Use

1. Estimate the landscape water needs for a typical suburban development with 100% turfgrass lawns and communal area given 21 home and the landscaped areas given in Table 2 and the climate data from Unit 4 for the month of July ~~growing season of May Sept~~.
   - Household outdoor water use = compute monthly water consumption during growing season if all of the landscaped area is turf
   - Communal landscaped area = compute monthly water consumption if all the green space in the development is turf

2. Design a "water sustainable" landscape plan implementing concepts learning in Units 4 and 5.
   - Design water-efficient yards for the houses and water-efficient landscapes for the communal green spaces. Use the methods applied in Unit 4.
   - How much irrigation water can be saved with rainwater harvesting? (if you captured all of the rainwater from the house roof tops?)
   - Compute the water consumption of the "water sustainable" development plan.

3.2 Indoor Water Use

1. What is the "typical" indoor water use for a suburban development of 21 homes?
   - Household indoor water use = 8,400 gallons per month per household of four people in the US (http://www.epa.gov/WaterSense/pubs/indoor.html)

2. Propose strategies to reduce indoor water use from Unit 5
   - How much water can be saved with water efficient fixtures?
   - Here is a link to a water use calculator that you can use to get some rough estimates of how much you can save by implementing low-water-use fixtures in a home: http://www.cob.org/services/utilities/water-calculator.aspx
   - Other strategies? e.g., grey-water recycling, alternative sanitation

Assessing Geoscience Literacy

Student Identification Number □□□□□□□□□□□□□□□□□□

GLE Pre and Post Survey
Form Number: 1

Instructions
Please fill in each bubble completely using black ink or #2 pencil. The system will not recognize partly-filled bubbles, check marks, or X's. Do not write outside the bubbles, except to write your student identification number.

1. Natural hazards can be put into two major categories. Some natural hazards can be made worse by humans; others are largely independent of human activities. Select the natural hazard least likely to be affected by human activity.

- (A) A. Forest fires
- (B) B. Tsunami
- (C) C. Landslides
- (D) D. Coastal erosion

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Lessons Learned

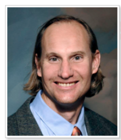
Lessons Learned

- **Underestimated Time.** Need time to coordinate, cross disciplines, assess, and revise teaching materials
- **Interdisciplinary = More Lessons.** Our first iteration of the module had enough class sessions for 50% of an entire class!
- **Sustainability = More Expertise.** Water sustainability needs more than geoscience and engineering (we knew this, but it was confirmed in this process)
- **Flipped Classroom Needs Assessment.** Like assigned reading.
- **Collaborative Curriculum Development = Rich.** Coherent module meshing variety of teaching and learning styles and ideas.
- **Collaborative Curriculum Communities (i.e., "open source") = Opportunity.** Future of higher education?

Adapting to Your Courses

Instructor Stories

These stories describe how the module was adapted for use in three different courses at three institutions. We hope these stories inspire your own use of the module and give you insight into how to adapt the materials for your classroom.



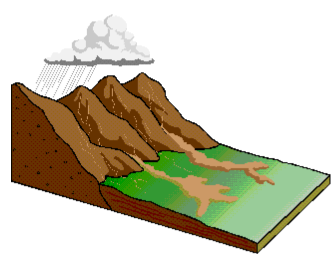
Steve Burian: Water Sustainability in Cities at the University of Utah. The module was used over a 3-week period in an introductory undergraduate general education course. The course, titled Water and Sustainability, was part of the Block Sustainability General Education sequence and was part of the required courses to acquire the Undergraduate Sustainability Certificate. The course had six students enrolled from several disciplines at the freshman and sophomore level. The course type (freshman and small) provided a different setting to apply the module materials. The module was adapted slightly for the freshman level students by (1) reducing activities in Units 3, 4, and 8 and (2) reducing expectations on deliverables of in-class assignments and the project.

Manoj Jha: Water Sustainability in Cities at North Carolina A&T University. I used this module in the 2nd half of the senior level design course (all units via 9 classes). Unit 9 was used as a term project as a mean for the assessment of the entire module. The class had 13 students with backgrounds mostly in Civil Engineering and some in environmental sciences. The course is designed to educate students interested in water infrastructures with the concepts of fundamental design methods and also supports students with the knowledge and practice examples for Fundamentals of Engineering (FE) licensing exam. It meets departmental goals of providing students with design experiences of water infrastructures.

Gigi Richard: Water Sustainability in Cities at Colorado Mesa University. The Water Sustainability Module was implemented for the last three weeks of a 200-level environmental geology course with 14 students. The course is a required course for Environmental Geology majors, and a restricted elective for Geology majors. The students varied from sophomore to senior level in the geosciences with the majority of them being sophomores and juniors. The module content had to be reduced to accommodate nine 50-minute class periods, instead of 75-minute class periods, so Unit 7 was not used. The module was used in lieu of the usual coverage of water resources in the course. The summative assessment (unit 9) was used as the final exam with an individual essay followed by group presentations. Also, the class does not meet in a computer classroom, so additional adaptations were made to adjust for the lack of computers. The flipped classroom approach was well-received by the students. The students were especially engaged during the classroom activities.

Marshall Shepherd: Water Sustainability in Cities at the University of Georgia. The module was used over two weeks in an Applied Climatology in the Urban Environment course with 16 students (a mixture of undergraduate and graduate students. The background of the students in the course included Geography, Remote Sensing, Atmospheric Sciences, Business, and Planning. This course was intended to draw on a wide range of experience but most students take the course for their Geography degree or Atmospheric Sciences Certificate requirements. The course explored past, current, and emerging textbooks and literature to introduce (1) fundamental concepts of the urban-climate system, (2) observational and modeling strategies for studying the urban-climate system, and (3) context for how urban-climate system feedbacks fit into the climate change discussion.

Thank You!



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