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

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Outline

1. NSF-funded InTeGrate Project @ SERC
2. Course Module
3. Pedagogy
4. Assessment
5. Lessons Learned
Two goals:
- National impact on increasing students in STEM
- Address grand challenge: environmental sustainability and resource limitations

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

1363 Community Members
- 687 workshop participants
- 115 curricular developers
- 69 Implementation Program participants

55% female
12% under-represented minority
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

Information for Materials Developers

Please read the "InTeGrate Material Developer" page in InTeGrate. This inception page outlines new ways you can start working with your team to create and sustain meaningful classroom experiences. Analyze the steps you want to take and provide an overview for how the process of material development works:

- **InTeGrate Materials**: The standards-based curriculum for integration of topics and activities, which outline the process of materials development. The steps are listed below:
  - Developing the Right Problem Set: This involves defining the problem set for your materials and selecting a problem set that is relevant to your students.
  - Writing the Materials: Once you have defined the problem set, you can start writing the materials. This involves creating a narrative that explains the problem set and how it is relevant to your students.
  - Reviewing the Materials: The materials are then reviewed by experts to ensure they meet the standards.
  - Finalizing the Materials: The final version of the materials is then created and made available for use.

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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

Instructional Analysis

Course Goals

Course Objectives

Criterion-Referenced Tests

Instructional Strategy

Development and Delivery of Instruction

Entry Level Characteristics

Assessment and Revision
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
Target Students and Courses

A great fit for courses in:

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

Module Structure

Unit 1: Module Introduction
Unit 2: Urban Hydrology
Unit 3: Urban Water-Atmospheric Environmental Interactions
Unit 4: Urban Landscapes and Water Use
Unit 5: Net Zero Water Buildings
Unit 6: Rainwater Harvesting
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

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 conservation 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 Group 1 worksheet enter:
- Total Employees (FTE) = 80 (60 male, 20 female)
- Visitors = 100 (80 male, 40 female)
- Students = 30 (20 male, 10 female)
- No employees on floor 1 or 2
- No visitors on floor 1 or 2
- No students on floor 1 or 2

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 ft² 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

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

<table>
<thead>
<tr>
<th>Unit 9 learning goal addressed</th>
<th>Module learning goal addressed</th>
<th>Review Criteria</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>L, 3, 4</td>
<td>1</td>
<td>Clearly explains the triple bottom line as a framework, why multi-development proposals are more sustainable than a typical development.</td>
<td>Exploration does not address sustainability and no evidence of application of triple bottom line principles, or major misconceptions are present.</td>
<td>Core explanation of how the triple bottom line was used to evaluate three proposals.</td>
<td>More sustainable than a typical development.</td>
<td>Includes demonstration of understanding of the concepts of sustainability and triple bottom line.</td>
</tr>
</tbody>
</table>
Assessment

**Explain water sustainability concepts**

Kennecott Building: Education through Water Sustainability

**Assessment**

Use systems thinking to enhance water sustainability in cities
Assessment

### 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](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: 40.551660/-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 (Unit 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 result 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 events.

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**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% turf (lawns and commercial area given 21 hr/week and the landscaped areas given in Table 2 and the climate data from Unit 4 for the month of July). Assuming all of the non-irrigated turf is turf.
   - Household outdoor water use: compute monthly water consumption during growing season if all of the non-irrigated area is turf.
   - Commercial/landscaped area: compute monthly water consumption if all the green space in the development is turf.

2. Design a “water sustainable” landscape plan implementing (concept) learning in Units 4 and 5.
   - Design water efficient yard for the house 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 25 homes?
   - Household indoor water use = 6,400 gallons per month per household of four people in the US [http://www.epa.gov/WaterSense/pubs/indoor.htm](http://www.epa.gov/WaterSense/pubs/indoor.htm)

2. Propose strategies to reduce indoor water use from Unit 5.
   - How much water can be saved with water efficient fixtures?
   - Here’s 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.epa.gov/energy/tools/water-calculator.aspx](http://www.epa.gov/energy/tools/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. Forest fires
☐ B. Tsunami
☐ C. Landslides
☐ D. Coastal erosion

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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 you to adapt the module to fit your own courses.

1. Adapting the Water Sustainability module at North Carolina A&T University

   The Water Sustainability module was designed for the first-year civil engineering program at North Carolina A&T University. The module was adapted for use in a sophomore-level design course at North Carolina A&T University. The module was designed to introduce students to the basic principles of water sustainability, including water cycle, water use, and water conservation.

2. Adapting the Water Sustainability module at the University of Utah

   The Water Sustainability module was adapted for use in an upper-division environmental engineering course at the University of Utah. The module was designed to introduce students to the basic principles of water sustainability, including water cycle, water use, and water conservation.

Thank You!

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