An Interdisciplinary Learning Module on Water Sustainability in Cities

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Abstract

As part of the National Science Foundation InTeGrate project, an interdisciplinary course module on Water Sustainability in Cities has been created by professors with backgrounds in civil engineering, hydrology, and atmospheric sciences at four higher education institutions in the United States. The module has nine units, with each unit composed of one or more 75-minute lessons. The materials introduce concepts related to sustainability and sustainable design of water infrastructure, urban hydrology, urban climate and evapotranspiration, water demand and stormwater runoff, water infrastructure, green infrastructure, extreme events, and planning. These concepts are delivered in interactive lecture and flipped classroom modes. Data-driven examples, case studies, and an integrative planning and design exercise provide guided and independent learning opportunities. The module includes explicit formative and summative assessment elements, culminating in the team project. After the materials were created, the module was reviewed for quality by independent experts, revised by the instructor team, pilot tested, assessed, revised again, and made available online. The pilot testing was conducted in four different courses, at a variety of undergraduate student levels (freshman to senior), and at different institutions. The pilot testing helped to identify areas to improve as well as approaches to adapt the module to different types of courses and different styles of teaching, all of which has been recorded in instructor guidance online. The effectiveness of the module in the pilot tests was assessed in terms of changes to student attitudes and motivations with regards to environmental sustainability. Student learning is also lightly assessed. This paper describes the module content and assessment, the process of development, and lessons learned about the interdisciplinary and multiple instructor design and testing of an instructional module.

Introduction

Water infrastructure in cities needs to provide a critical lifeline to deliver reliable quantities and qualities of water. However, in much of the world, water infrastructure is facing a challenge to meet user demands, and perform adequately under influence from growing populations, aging systems, contaminants, and climate change; the ultimate challenge is to transform under these complex circumstances to be sustainable[1-3]. This growing concern about water sustainability is leading to widespread discussion among scientific and engineering communities about needs for maximizing use efficiency, conservation, and recycling of water in urban areas[4,5]. In this sense, local water resources such as harvested rainwater and treated graywater, and water efficiency measures such as low water use landscaping are being integrated into cities as sustainable approaches[1,6,7]. However, to support these advances in water infrastructure, educational programs must co-evolve to train the Community of Practice that decides how to configure water systems through an interdisciplinary lens and operate them in concert with stakeholders in sustainable ways[8-10].

In response to the need for education to provide the trained workforce for water sustainability and other sustainable practice demands, numerous degree programs and courses have been created[11]. And educators have in turn developed approaches to support learning of sustainability principles, practices, and skills in engineering education[12,13]. The progress in developing effective educational approaches has been inhibited for many reasons, including institutional barriers, constrained curriculum, resistance to change, and lack of incorporating social sciences and other disciplinary perspectives. To overcome these challenges, a variety of approaches have been designed to infuse sustainability concepts and techniques into engineering courses and curricula[14-28]. These ideas include actions such as modifying learning objectives to include sustainability perspectives, incorporating sustainability knowledge and skills into learning activities, exposing students to sustainability ideas using co-curricular experiences, cross-institution collaborative learning, and creating new learning modules and even entire courses.

This paper describes the creation of an interdisciplinary module on the topic of Water Sustainability in Cities. The module contributes to meeting a need for *accessible* teaching materials to help advance the knowledge and skills of students addressing complex and dynamic problems with water infrastructure in cities. The module creation also provided insight into the development of interdisciplinary education modules by multiple instructors from different disciplines and different institutions, a possible approach for the future. The paper therefore has two goals: (1) to present the Water Sustainability in Cities course module and make available for others to incorporate into water sustainability programs and (2) to share the experience of developing a quality-assured, multi-instructor approach to develop a learning module.

Module Description

The Water Sustainability in Cities course module described in this paper addresses the grand challenge of water sustainability, and includes elements of instruction to help students learn hydrologic and atmospheric processes, clean water systems, low-impact development, green infrastructure, flood risk, and climate variability. The Learning Goals of the module are:

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

The module duration is designed to be four weeks of classroom instruction, consisting of nine lessons:

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

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

Following the modular design philosophy and to maximize adaptability, the individual lessons are stand-alone units of instruction sufficiently independent to be delivered individually or in small sets without loss of effectiveness. The module is designed to achieve a hierarchical set of learning objectives following the well-known Bloom's Taxonomy of Educational Objectives. The module materials development followed the National Science Foundation (NSF) InTeGrate Project rubric for Materials Development and Refinement (http://serc.carleton.edu/integrate/info_team_members/currdev/rubric.html).

The content of each lesson described below highlights importance of the topic, lists lesson learning objectives, and presents highlights of the learning activities. All lesson materials and descriptions of applications are available through the module web site (http://serc.carleton.edu/integrate/teaching_materials/water_cities/index.html). Online, each lesson portal provides learning goals, context for use, pre-class activities, in-class activities, assessments, instructor resources, and teaching tips. All learning materials are provided.

Lesson 1 (Introduction) introduces the course module by establishing the foundation definitions of sustainability, sustainable development, and water sustainability in cities. Sustainability concepts are introduced using pre-class videos (flipped classroom style) and examples examined in class to explain water sustainability in cities. Students are engaged in activities to help them explore the definitions of water sustainability in cities and apply systems thinking. The unit materials are designed with flexibility in mind such that instructors can adapt the module to their own courses and context. The unit may also be used on its own to provide an introductory water sustainability lesson without using other units in the module.

Lesson 1 Learning Objectives:

- Identify challenges and solutions to water sustainability in cities
- Define water sustainability in the context of cities
- Explain systems thinking, triple bottom line, Cradle to Cradle, and other sustainability concepts and describe their relationship to water
- Describe, using systems thinking terminology, the interconnections of a water system to infrastructure, governance, people, economy, and other systems in cities

Lesson 2 (Urban Hydrology) engages students in learning activities to advance their knowledge of the water cycle, both from natural and urban system perspectives. Students gain a basic understanding of the natural and urban water cycles, their components, and the impact of urbanization on runoff. Through brief lectures and discussion periods, solution of example problems, and a group activity, students gain comprehension of the water cycle components, their spatial and temporal variability, water budget calculation, and the impacts of urbanization on surface water.

Lesson 2 Learning Objectives:

- Compare and contrast natural versus urban water cycle
- Define the components of the urban water cycle
- Explain the spatial and temporal variability of the water cycle
- Calculate water budget components
- Recognize and quantify the impact of urbanization on surface water

Lesson 3 (Urban Water - Atmospheric Environment Interactions) addresses concepts related to urban-atmosphere interactions. The content explores how urban landscapes and atmospheric constituents modify or interact with the atmosphere to affect temperature, clouds, rainfall, and other parts of the water cycle. Fundamental concepts of weather and climate are established. The unit then transitions to focus on the "urbanized" environment and its complex interactions with the atmosphere. Students learn about interactions such as 1) urban modification of surface temperature and energy exchanges; 2) water cycle components; 3) cloud-rainfall evolution within urban environments; and 4) applications to real societal challenges like urban flooding.

Lesson 3 Learning Objectives:

- Identify the atmospheric components of the water cycle
- Explain the impact of urbanization on weather, climate, and the water cycle
- Differentiate between an urban heat island and an urban climate archipelago
- Use geo-visualization and scientific analysis software to apply systems thinking to urban-climate interactions

Lesson 4 (Urban Landscapes and Water Use) introduces evapotranspiration (ET) and how ET varies with meteorological factors and plant factors. A pre-class video (flipped classroom) and worksheet introduce students to estimating landscape water needs from ET and precipitation data. In class, students design low water-use landscaping plans and calculate the water savings of water-efficient landscaping compared with turf grass.

Lesson 4 Learning Objectives:

- Discuss the variation in evapotranspiration with temperature, relative humidity, wind and available water
- Relate plant evapotranspiration to plant consumptive use of water
- Estimate irrigation needs of different types of vegetation based on given plant factor and reference evapotranspiration rates
- Design an urban landscaped area and evaluate its water use over a summer growing season
- Relate water-efficient landscaping to water sustainability in cities

Lesson 5 (Net Zero Water Buildings) addresses the concept of Net Zero Water of buildings. Net Zero Water can be defined in different ways. For this module it means a building's water needs are supplied 100% from harvested rainwater and/or water that is recycled on site. Reducing indoor and outdoor water use is a key element. Reading and videos are assigned to aid students grasping the concept of Net Zero Water as applied to buildings. A spreadsheet tool from the U.S. Green Building Council is introduced and used to estimate indoor water demand for baseline and design (water conservation) scenarios. In addition, this unit links to Lesson 4 by including an estimate for outdoor water demand. The central activity for the unit is an active learning team exercise to analyze indoor water use reduction for a case study building and evaluate Net Zero Water.

Lesson 5 Learning Objectives:

- Explain concept of Net Zero Water buildings
- Calculate indoor water demand of a building
- Quantify impact of conservation practices and technologies on indoor water demand
- Assess potential of Net Zero Water for a building

Lesson 6 (Rainwater Harvesting) covers the preliminary design of a rainwater harvesting unit. Pre-class assignments provide background on rainwater harvesting. An active learning exercise steps student teams through the process of sizing a rainwater harvesting cistern (Fig. 1), using water demand estimates from Lessons 4 and 5. The activity leads into a revision of the water system mind map developed in previous units.

Lesson 6 Learning Objectives:

- Describe rainwater harvesting systems in urban areas
- Calculate storage capacity required for rainwater harvesting system
- Apply water balance to determine size and performance of a rainwater harvesting system

Figure 1. Cistern used for rainwater harvesting in North Carolina (Source: Dwane Jones)

Lesson 7 (Low Impact Development and Green Infrastructure) continues the use of the Case Study established in Units 4-6 to explore water sustainability in the context of a building. The activity is extended to the catchment level, and a new tool for catchment level storm water management is introduced. Students are exposed in the pre-class assignments to low impact development (LID) and green infrastructure (Fig. 2) and the EPA National Stormwater Calculator. In class, the central activity is applying the EPA National Stormwater Calculator to evaluate an LID control plan for the building case study. The unit brings together concepts from previous units through the use of the calculator. The impact of landscapes, buildings, and other features on storm water runoff is illustrated. And the potential benefit of LID controls is analyzed. The homework assignment engages students in the search for a local green infrastructure site and summarize in the context of a sustainable site.

Lesson 7 Learning Objectives:
- Describe low-impact development storm water management controls
- Apply the EPA National Stormwater Calculator to determine storm water management benefits of low-impact development controls

Figure 2. Rain garden in Cottonwood Heights, Utah as an example of green infrastructure elements that require interdisciplinary knowledge and skills bridging geoscience and engineering.

Lesson 8 (Impacts of Extreme Hydroclimatic Events) covers the basics of hydroclimatic extreme events with a focus on floods and droughts. Topics include introduction to floods and droughts, impact of urbanization on extremes, how to understand and predict extremes, how to tackle them (management strategies), and elements of urban climate resilience. The teaching strategy is designed with short and divided lectures filled with discussion questions and a group activity. Students will be working with time series flow data for statistical analysis of extreme events.

Lesson 8 Learning Objectives:
- Define the meaning and explain the characteristics of extreme events (floods and droughts)
- Collect and perform statistical analyses on geoscience data
- Recognize the usefulness of geoscience data in engineering design and application
- Evaluate potential measures to address extremes
- Reflect on key elements of a resilient urban water system

Lesson 9 (Planning and Decision Making) is a group activity that requires students to apply the material they have learned in Lessons 1–8 in an urban water system design project. Students are presented with a scenario and are required to select options to design a feasible and sustainable urban water system that considers the triple bottom line. The design project requires students to consider hydrologic processes (e.g., evapotranspiration, runoff) in designing outdoor landscaping and the amount of pervious and impervious area for the site. Students explore the use of indoor water use efficiency and other methods (e.g., rain barrels) to reduce water consumption. Students are also asked to consider the connection between urban development and atmospheric processes. Students apply systems thinking by connecting hydrologic and atmospheric processes with the human built system. In the end, student groups present their design to the class and critique each other's designs. The resulting report from these activities is used for summative assessment of the entire module.

Lesson 9 Learning Objectives:

- Plan a sustainable urban water system for a particular scenario
- Articulate pros and cons of water system options
- Describe their consideration of the triple bottom line in their design decisions
- Communicate a plan via a poster presentation and short oral report illustrating their decision matrix
- Assess the group plans and select and defend which plan is most feasible and sustainable

The lessons provide a foundation of learning about urban water systems, basic hydrologic and atmospheric processes, and sustainable and resilient infrastructure planning, design, and decision making. Lessons typically use data-driven exercises and several use the flipped classroom pedagogical approach.

Module Development

This project brought together four professors from engineering and geoscience disciplines at four institutions (University of Utah, Colorado Mesa University, University of Georgia, and North Carolina A&T University) to develop an interdisciplinary course module. Guided by a curriculum development support team, the professors followed the NSF-funded InTeGrate (http://serc.carleton.edu/integrate/index.html) approach. All modules developed under the InTeGrate program have to meet the following requirements:

- address one or more grand challenges involving the Earth and society,
- develop student ability to address interdisciplinary problems,
- improve student understanding of the nature and methods of science and developing geoscientific habits of mind,
- make use of authentic and credible science data to learn central concepts in the context of scientific methods of inquiry, and,

- incorporate systems thinking.

All teaching materials were developed and tested by the faculty teams and sought to bring together perspectives from different types of institutional settings. The collaborative development sought to create robust, flexible materials that could be used effectively in a wide variety of settings. This was deemed as key to creating materials that can be adopted easily by faculty who are not involved in the development.

The team-based materials development process included review using a Materials Development Rubric and collection of project wide assessment data. The added benefit of the development process was expected to be increased faculty skill in materials development, teaching, and evaluation of student learning. It also was expected to encourages cross-institutional collaborations and lead to the development of more interdisciplinary and cross-disciplinary teaching materials.

The team developed and tested the materials over a three-year period. This included workshops, a continuous development and review process, pilot testing, and revision and refining. The team was supported by a team mentor (co-author John Taber) who provided overall guidance from the InTeGrate project leadership team, an assessment consultant who assisted the team in meeting the materials development rubric and in interpreting the testing results, the project internal assessment team who assisted in the data collection effort during testing, and a member of the InTeGrate web design team who assisted with use of the content management system to create and publish materials and to manage the interactions among the team. More details about the teaching materials development process is available at the InTeGrate web site (http://serc.carleton.edu/integrate/about/teaching_materials.html).

Assessment Approach

The project had two assessment phases. First, the teaching materials were reviewed in three steps. Step 1 involved a review by an assessment expert following the NSF InTeGrate course module assessment rubric (http://serc.carleton.edu/integrate/info_team_members/currdev/rubric.html). Step 2 involved review by a content expert. Step 3 was a final technical review to make sure all online content was clear and operational. Revisions were required at each step and managed by the InTeGrate mentor.

The second assessment phase was to pilot the module and measure student attitudinal and aspirational changes, as well as student learning gains. For the pilot tests, 41 students in four courses completed the module at four institutions (University of Utah, Colorado Mesa University, University of Georgia, and North Carolina A&T University). The four courses and number of students were:

- Sustainability and Water is a freshman/sophomore course at University of Utah. 8 students (4 environmental and sustainability studies, 2 engineers, and 2 biology majors) completed all lessons.

- GEOL 250 is a required sophomore level course for Environmental Geology majors, and a restricted elective for Geology majors, at Colorado Mesa University. 12 Environmental Geology students completed all lessons.
- Hydrology is a required junior level course for civil engineering majors at North Carolina A&T. 13 civil engineering students completed all lessons.
- Applied Climatology in the Urban Environment is a required junior level course for geography and atmospheric sciences majors at University of Georgia. 16 geography or atmospheric sciences students completed the first four lessons.

All students were subjected to three assessment instruments:

1. The InTeGrate Attitudinal Instrument (IAI) (http://serc.carleton.edu/integrate/about/iai.html) was administered online to students before and after the module. The IAI assesses students' interest in careers and college majors related to the Earth and Environment and students' motivation to contribute to solving grand challenges of environmental sustainability, depletion of natural resources, and natural hazards. Interestingly, the course module described herein is one of a few engineering related modules to have the IAI applied.
2. The Geosciences Literacy Exam (GLE) (http://serc.carleton.edu/integrate/about/assessment.html#gle) survey questions were administered in hard copy before and after the module to quantify the effectiveness of the course module materials on students' geoscience literacy. The GLE instrument contained eight questions addressing content and concepts in the Earth, Climate, and Ocean Science literacy documents. The GLE is best suited for upper-level geoscience majors.
3. Student learning targeting lesson learning objectives were assessed with formative instruments. A summative assessment was also provided in the form of a team project. Student learning was assessed for this paper by reviewing performance of students on the team project.

Assessment Results

IAI

Figure 1 presents results from the IAI post-module survey question gauging student interest in an Earth-related career. The students completing the Water Sustainability in Cities course module have a higher initial and post-module interest in an Earth-related career compared with all respondents from the InTeGrate project. We do see nearly 30% increase of students completing the module changing their attitude from a low interest in Earth-related career to a high interest in an Earth-related career. Figure 2 presents results of the IAI survey question assessing the change in student motivation to create a sustainable society. The results indicate 50% of the respondents changed from before the module to after the module from low to high motivation, an indicator that the students became more motivated by completing the module to create a sustainable society.

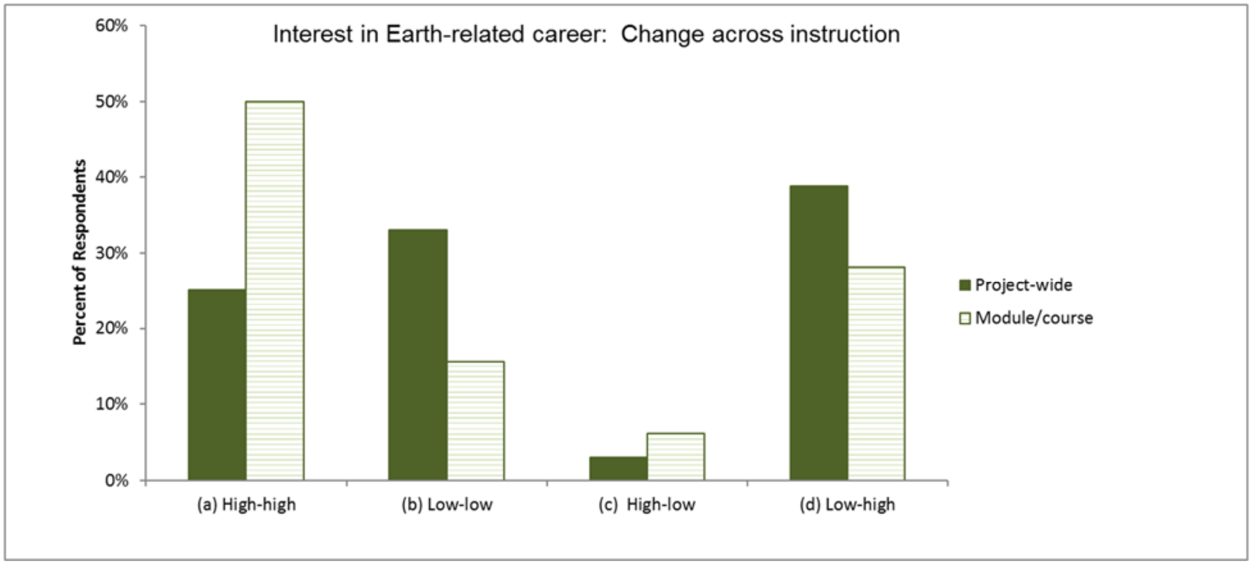

Figure 1. IAI results assessing change in student interest in Earth-related career after completing the module (n=31), compared with results of all survey respondents completing all modules of the NSF InTeGrate project.

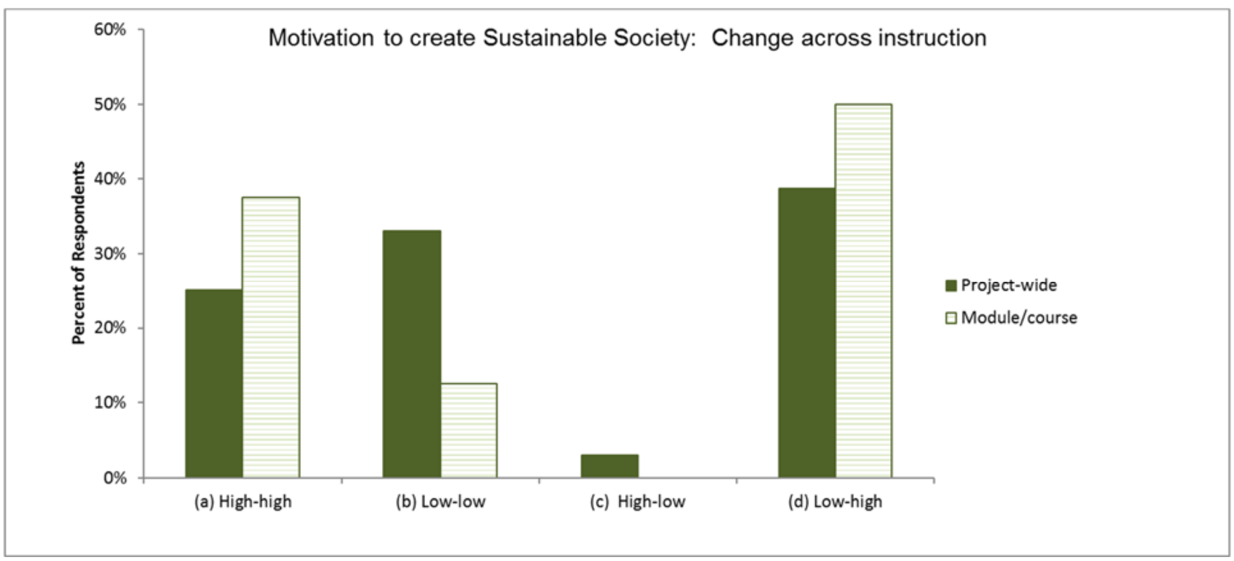

Figure 2. IAI results assessing change in student motivation to create a sustainable society after completing the module (n=31), compared with results of all survey respondents completing all modules of the NSF InTeGrate project.

Consistent with the results displayed in Figures 1 and 2, Figure 3 shows results confirming a change in attitude of students after completing the module. In the case of Figure 3, we see students express an increased motivation to work for an employer with sustainable practices. Overall, Figure 4 summarizes the environmental concern based on a composite index of seven questions rating the concern of students for seven environmental issues (global climate, population growth, meteorological impact, biodiversity loss, energy limitations, water limitations, and mineral limitations). It is important to note that student responses on the questions about water limitations showed the greatest increase in concern. Lastly, one IAI question asked students to think about the future, and then envision if they can use what they have learned in the course module to help society overcome problems of environmental degradation, natural resources limitations, or other environmental issues. 90% of the 31 respondents indicated 'yes'.

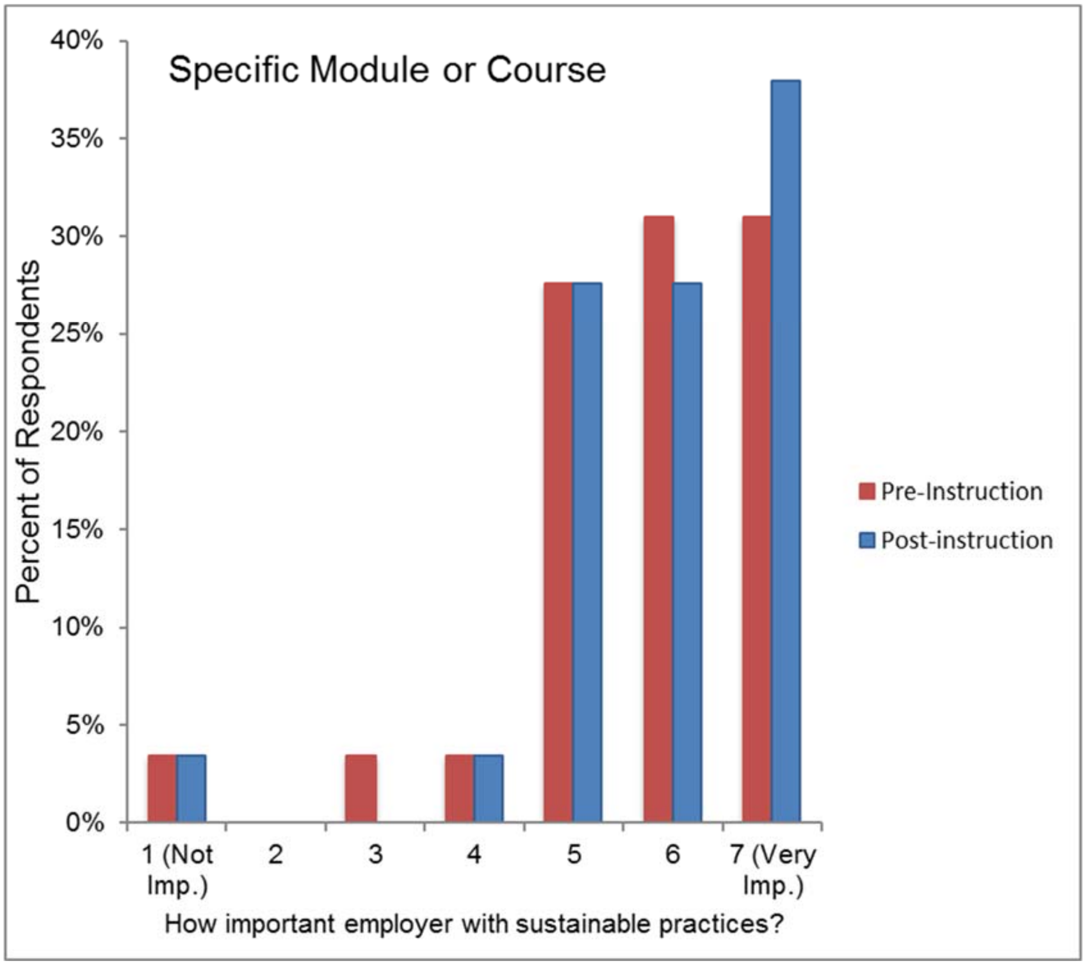

Figure 3. IAI results assessing change in student motivation to work for an employer with sustainable practices after completing the module (n=31).

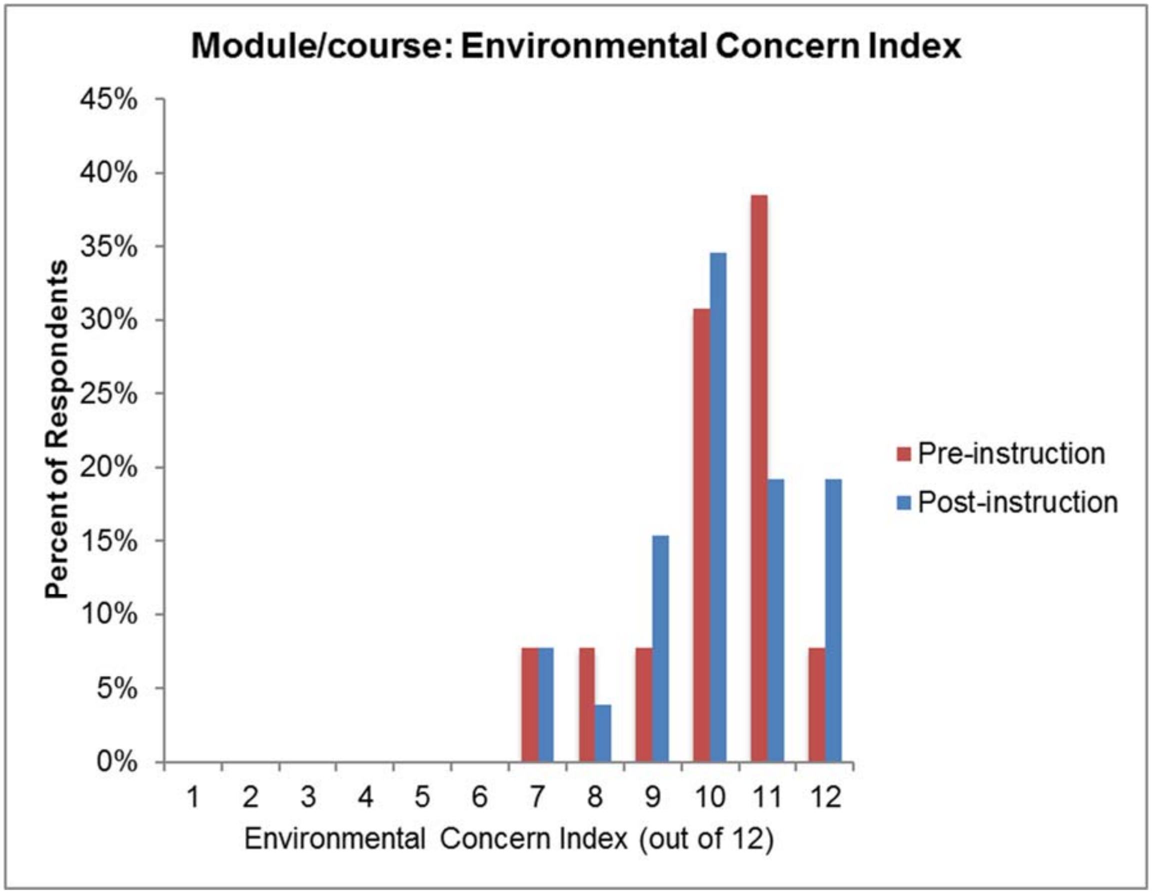

Figure 4. IAI results indicating the composite student environmental concern based on responses to 7 questions before and after the module (n=31).

GLE

For this particular course module, the coverage of basic geosciences was limited. There was an introductory lesson on applied urban hydrology and a lesson an applied urban climate. However, the depth of coverage was limited and the breadth across geoscience was not included. Therefore, the expectation was for minimal improvement on the GLE questions, and this was confirmed by the results from the four pilot tests. In fact, for the 31 respondents the average change in survey score (number of correct answers to the questions) was a reduction of nearly one correct response. The survey confirmed the expected.

Summative Assessment of Student Learning

Student learning was also assessed with formative and summative assessment instruments as described in the online course materials. The module goals were assessed with the following instruments:

- Goal 1: Explain water sustainability concepts (assessment: quizzes)

- Goal 2: Use systems thinking to enhance water sustainability in cities (assessment: mind map)
- Goal 3: Apply knowledge and skills from atmospheric science and hydrologic science in planning and engineering contexts (assessment: individual homework exercises)
- Goal 4: Create and evaluate alternative plans to improve sustainability of water management systems in cities (assessment: team project rubric)

The assessment of Goal 4 also served as the summative assessment associated with the student's ability to accomplish the learning objectives of Lesson 9, which corresponded to the grading of the team project using the rubric included in Appendix 1 (the other assessment instruments for the module are provided online). All student teams successfully completed the team project, with the vast majority of marks of 2 or 3 for the goals listed in the rubric. Ideally, student learning in unmodified courses would have been compared to the courses including the module. However, the assessment was only completed for modified courses.

Summary and Instructor Reflection

This paper presented a new course module providing instructional materials on the topic of Water Sustainability in Cities. The module materials were created following the NSF Integrate materials development process, with reviewers evaluating the quality of the module with respect to a rubric, content, and online operational effectiveness. The module was pilot tested at four institutions in engineering and non-engineering courses. A final revision was completed after instructor self-assessment. And then the module was published. Student learning was confirmed using formative and summative assessment. Students gained an appreciation for environmental issues and developed a motivation to work for companies practicing environmental sustainability. Students also gained an awareness of and concern for environmental problems.

Overall, the module instructors increased their belief in the benefits of integrating engineering, geoscience, and other disciplines together in the instruction of sustainable water design in cities. However, it was concluded that creating a module with this level of quality and incorporating perspectives of multiple instructors required significant time and effort beyond what is required to prepare a course designed by one instructor. In fact, the amount of time invested by the faculty members amounted to more than three times what would normally be used to create draft lessons for delivery. Although requiring more time, the process led to several key strengths noted after reflecting on the pilot testing of the module:

- The module effectively fuses geoscience elements of hydrologic science, atmospheric science, and biological science with sustainability concepts, systems thinking, planning, and engineering at the introductory level in a manner that illustrates the value of this diverse knowledge for urban water system planning.
- The variation of use of flipped and traditional delivery with consistent use of data-enabled exercises, and using a place-based case study kept students engaged.
- 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. And this was demonstrated by pilot testing individual and sets of lessons.

- Based on student feedback from the pilot tests, the team project was identified as the most important element of the module for helping students to understand the interconnections among geosciences and engineering in water sustainability.

After additional reflection on the process, the professor team noted the following lessons learned about collaborative curriculum development:

- Collaborative development of materials takes more time than independent development, but leads to better integration of content from different disciplines.
- Online tools are needed to aid the asynchronous materials development.
- Having a curriculum development team with oversight is essential for quality control and consistency of online materials development; however, this leads to uncertainties, points of confusion, and delays, which cumulatively lengthened the process.
- The major challenge with delivering these modular teaching materials with interdisciplinary content is the lack of pre-requisite knowledge and skills among all the different students.
- The sustainability of the teaching materials requires the creation of a Community of Practice to carry on the continuous review and improvement, which has not happened with this project.

Overall, the instructors feel generating a high quality course module that can be disseminated through the Internet warrants the necessary time and effort and the following of a strict process for quality assurance as mandated by NSF InTeGrate. The broader benefits for many instructors and students that use the material far outweigh the increased time and effort required of the developers.

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Appendix I - 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.
	2	**Clear application of systems thinking to the coupled urban-natural hydrologic and atmospheric systems**	No mention of systems and no evidence of systems thinking	Some evidence of systems thinking, but not explicit		Presentation demonstrates application of systems thinking and recognition of potential feedbacks and coupled human-natural systems

	3	**Demonstration of understanding of the impact of urban development on the hydrologic cycle and atmospheric processes**	No connection demonstrated between urban development and hydrologic and atmospheric processes, or major misconceptions are present			Clearly explains throughout presentation the connection between urban development and hydrologic processes, and how urban development impacts hydrologic processes
Review of sustainable design: Reduction in water consumption						
1	**1**	• **Explanation of implemented sustainable strategies for reduction of water consumption in the landscape and in the buildings**	Sustainability of chosen design is unclear			Clear description of a sustainable design that utilizes methods to reduce water consumption
1, 2	**3**	• **Explanation of rationale for their selection of strategies including the scientific basis**	Lack of explanation re. why certain strategies were chosen			Clear explanation re. why strategies were chosen including the scientific basis for their selection.
		• **Documentation of their work with defensible calculations**	Major confusion or mistakes in the methods and major errors in results	Calculations mostly done correctly, but some mistakes in the methods	Calculations done correctly, but some minor mistakes like errors in unit conversion	Calculations done correctly
	4	• **Evidence of iteration on different options**	No iteration on different options			Iteration between different options in decision process resulted in selection of chosen strategy
Review of sustainable design: Reduction in stormwater runoff						
1	**1**	• **Achieved sustainability goal of developed runoff = natural runoff**	Sustainability of chosen design is unclear and no attempt made to reduce developed runoff to natural levels			Consideration of stormwater in sustainability of design and clearly achieved goal of reducing developed runoff to natural levels

1, 2	**3**	• **Explanation of their rationale for their selection of strategies including the scientific basis?**	Lack of explanation re. why certain strategies were chosen			Clear explanation of why strategies were chosen including the scientific basis for their selection
		• **Documentation of their work with defensible calculations?**	Major confusion or mistakes in the methods and major errors in results	Calculations mostly done correctly, but some mistakes in the methods	Calculations done correctly, but some minor mistakes like errors in unit conversion	Calculations done correctly
	4	• **Evidence of iteration on different options?**	No iteration on different options			Evidence of iteration on different options
3	**4**	**Estimation and explanation of cost of selected strategies**	No consideration of cost	Cost was considered, but not estimated or explained well	Cost was considered and estimated, but not explained clearly	Cost of different strategies was considered, estimated and explained
1, 3	**2**	**Accuracy and completeness of computations**				
4		**Quality of writing, presentation materials and oral presentation**				Clear presentation materials, presentation is organized and logical.
		Total score out of ___				