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Course Strategy: Threading Triple Bottom-Line Sustainability Across Multiple Courses

Dr. Daniel B. Oerther, Missouri University of Science and Technology

Professor Daniel B. Oerther, PhD, PE joined the faculty of the Missouri University of Science and Technology in 2010 as the John A. and Susan Mathes Chair of Civil Engineering after serving ten years on the faculty of the University of Cincinnati where he was the head of the Department of Civil and Environmental Engineering.

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Daniel B. Oerther
Missouri University of Science and Technology, 1401 N. Pine Street, Rolla, MO 65409

Abstract

The instructional environment for this study was the Missouri University of Science and Technology. Two courses offered through the Department of Civil, Architectural, and Environmental Engineering are discussed, specifically: CArE 2601 Fundamentals of Environmental Engineering; and CArE 5605 Environmental Modeling. The pedagogical approach to delivery of both courses included blended content delivery, a flipped classroom, and modified mastery learning. The approach to instruction and technology included conceptual understanding before spreadsheet modeling to verify concepts through application. The course content focused upon the topic of "triple bottom line accounting" (also known as "full cost accounting" or "true cost accounting"). This content was presented in the context of the United Nations Sustainable Development Goals (UNSDGs), where the three dimensions of sustainable development include economic (i.e., prosperity), social (i.e., people), and environmental (i.e., planet) considerations. One module asked the question, "how much would you pay for a sunset?" Another module asked the question, "how would you exchange transferrable discharge permits to create a low cost solution while ensuring a baseline for environmental services?" Student mastery learning to earn a grade of "C" was assessed through rapid feedback to quizzes administered via the Learning Management System (i.e., Canvas), and a buffet of optional assessment instruments to earn a grade of "B" or "A" included detailed grading of extended homework assignments performed individually. The rationale for the approach employed in these two courses includes a recognition that the practice of environmental engineering often is viewed as "driven by regulation". The long-term goal of threading triple bottom line accounting to teaching sustainability across multiple courses includes helping future Professional Engineers position themselves and their employers within the emerging conceptual framework of "environmental, social, and corporate governance" or ESG (i.e., for the PE in Environmental Engineering to lead the corporate role of Chief Sustainability Officer). The lessons learned through this study included: 1) integrating economics into the environmental engineering classroom provides an authentic context to understand the importance of adopting a systems-level view of the trade-offs inherent as part of the triple bottom line; 2) future work should explore replication of the results in courses offered by other faculty and at other institutions as well as more broadly disseminated results to encourage the adoption of similar approaches in other courses within environmental engineering curricula.

Introduction

In 2015, the United Nations adopted, "Transforming our World: The 2030 Agenda for Sustainable Development," also known as the UN Sustainable Development Goals or UNSDGs [1]. The preamble begins, "This Agenda is a plan of action for people, planet and prosperity … They [the 17 goals and 169 targets] are integrated and indivisible and balance the three dimensions of sustainable development: the economic, social and environmental." Measuring both the direct as well as the indirect costs (and benefits) of these three dimensions – people, planet, and prosperity – is known as “full cost accounting” or “true cost accounting” (i.e., herein known as “triple bottom line”). This triple bottom line varies from “standard accounting” in a number of important ways. For example, the value of goods and services are recorded even if no cash outlays are involved and lifecycle analysis is used to identify and incorporate hidden costs and externalities.

Among the sub-disciplines of engineering, the practice of environmental engineering is somewhat unique in that evidence strongly suggests that environmental engineering is subject to the “care penalty” [2]. The care penalty is an economic concept originally described by Dr. Nancy Folbre as part of her ongoing work on the economics of care, which she defines as, “work that involves connecting to other people, trying to help people meet their needs, things like the work of caring for children, caring for the elderly, caring for sick people or teaching is a form of caring labor,” [3]. As described previously, the definitions of environmental engineering published by the United States Bureau of Labor Statistics and incorporated into the Environmental Engineering Body of Knowledge are strongly related to “caring”, and a prior analysis of the demographics as well as the salaries of environmental engineers support the presence of a care penalty [2].

The care penalty in environmental engineering may be linked to the unpriced benefits of environmental engineering practice. For example, the application of standard accounting (i.e., “prosperity”) to the capital, design, construction, and operation of a municipal sewage treatment plant may not fully capture the “planet” aspects of treatment plant effluent being discharged better than required by law. Such a planetary benefit – exceeding the requirements of regulations – would represent an unpriced benefit to those who live downstream of the outfall (i.e., “people”). Therefore, to help students of environmental engineering understand the importance of triple bottom line accounting (i.e., considering the full benefits of Professional Engineering practice to prosperity, planet, and people), modules have been developed and used in two courses offered through the Department of Civil, Architectural, and Environmental Engineering at the Missouri University of Science and Technology.

This article describes a module that asks students in CArE 2601 Fundamentals of Environmental Engineering the question, “how much would you pay for a sunset?” And this article describes a module that asks students in CArE 5605 Environmental Modeling, “how would you exchange transferrable discharge permits to create a low cost solution while ensuring a baseline for environmental services?” CArE 2601 is a required course, and enrollment often includes sophomores working toward a baccalaureate degree in civil engineering, architectural engineering, or environmental engineering. CArE 5605 is an optional elective course, and enrollment often includes juniors or seniors in environmental engineering as well as graduate students pursuing a Master’s or a PhD in environmental engineering.

Data collected from multiple course offerings are summarized and discussed in the context of the long-term goal of helping future Professional Engineers position themselves and their employers within the emerging conceptual framework of “environmental, social, and corporate governance” or ESG.

Instructional environment

The instructional environment for this study was the Missouri University of Science and Technology, which is self-described as a "technological research university" or TRU. A TRU is characterized by a study body with more than one quarter of the total population studying engineering from baccalaureate through doctoral programs, an emphasis on research, and a strong liberal arts, humanities, and social sciences degree programs to complement the STEM-focus. Both courses presented in this paper are offered through the Department of Civil, Architectural, and Environmental Engineering; specifically CArE 2601 Fundamentals of Environmental Engineering (a required course, typically enrollment primarily from sophomores studying any of the degrees offered in the Department) [4] and CArE 5605 Environmental Modeling (an optional elective of undergraduate and graduate students, with enrollment primarily from juniors or seniors as well as those studying for a Master's or a PhD in Environmental Engineering) [5].

Delivery method

As described previously [6], the pedagogical approach to delivery of both courses includes blended content delivery (i.e., between 25 and 75% of course content is available online), a flipped classroom format (i.e., students interacting with content before meeting with instructor), and modified mastery learning (i.e., mandatory completion of required assignments to earn a grade of "C" and optional completion of additional assignments to earn a contract grade above a "C").

Approach to instruction and technology

The approach to instruction and technology includes conceptual understanding of concepts before spreadsheet modeling to verify concepts through application.

Topics covered

The course content focuses upon the topic of "triple bottom line accounting" (also known as "full cost accounting" or "true cost accounting"), which is different from "standard accounting" because the value of goods and services are recorded even if no cash outlays are involved and lifecycle analysis is used to identify and incorporate hidden costs and externalities. This content is presented in the context of the UNSDGs, where the three dimensions of sustainable development – economic (i.e., prosperity), social (i.e., people), and environmental (i.e., planet) are integrated and balanced through partnerships to achieve peace (i.e., the five "Ps" of the UNSDGs) [1].

A module incorporated into CArE 2601 asks students to explore the question, "how much would you pay for a sunset?" Within the context of this questions, students often respond with one of three answers, namely: 1) "everything, because its priceless"; 2) "nothing, because its free"; or 3) various monetary amounts typically ranging from $5 to $1,000. The instructor uses the example of the Tragedy of the Commons to explain how the "free" answer is inaccurate. The instructor uses the example of Opportunity Cost to explain how the "priceless" answer is inaccurate.

Finally, the instructor leads the students through the construction of a hypothetical spreadsheet with “pollution” on the abscissa, “cost of treatment” on the ordinate, and “cost of health” on the secondary ordinate. At low levels of pollution, the cost to health is low and the cost of treatment grows exponentially towards infinity. At high levels of pollution, the cost of treatment is low and the cost of health grows exponentially towards infinity. The total cost curve is represented by the sum of the two curves, and the instructor asks the students to construct models representing improvements in treatment technology as well as a combined cost of health that includes both the health of humans as well as the health of planetary ecosystems. Ultimately, the instructor is demonstrating to students that the correct answer to the question, “how much should you pay for a sunset?” is something like, “$200 for a waterfront room at the beach.” Details of the PowerPoint slides used in this lecture are included in Appendix A.

A module incorporated into CArE 5605 asks students to explore the question, “how would you exchange transferrable discharge permits to create a low cost solution while ensuring a baseline for environmental services?” which examines surface water treatment of effluent from the pulp and paper industry in the Athabasca River watershed of Canada. The instructor explains the governing equations that describe the physical, chemical, and biologically processes resulting in the degradation of streams impacted by the discharge of pollution. These equations are incorporated into a detailed spreadsheet and used to calculate the impacts of pollution along the Athabasca River, which runs for approximately 1,200 km from the icefield in Jasper National Park to Lake Athabasca. Historical data for water quality as well as costs associated with treating pollution before discharge are combined with the physical, chemical, and biological model. Within Excel, the Solver is used to identify a least-cost solution to the trade-off of transferable discharge permits constrained by the minimum quality of river water needed to maintain fish stocks. The purpose of the modeling exercise is to explicitly link planetary health, financial prosperity, and human health by introducing students to the populations of indigenous peoples living along the Athabasca River. Details of the reading assignments, the modeling exercise, and the rubric used to grade the work are provided in Appendix B.

Assessment

Student learning was assessed at the conceptual level through rapid feedback to quizzes administered via the Learning Management System (i.e., Canvas). These results have been previously discussed (i.e., [4, 6]) and examples of the questions included on quizzes are provided in Appendix C.

Student learning was assessed at the application level through detailed grading of extended homework assignments performed individually. These results have been previously discussed (i.e., [5, 7]) and examples of the homework instructions and grading rubric are provided in Appendix D.

Rationale for the approach

The rationale for the approach employed in these two courses includes a recognition that the practice of environmental engineering often is viewed as “driven by regulation” (i.e., polluters only eliminate pollution if required by law). The long-term goal of incorporating awareness of triple bottom line accounting in these two courses is to improve student understanding of alternative approaches to the practice of environmental engineering, which may help future Professional Engineers position themselves and their employers within the emerging conceptual framework of "environmental, social, and corporate governance" or ESG (i.e., [7]).

For example, resilience to climate change includes the possibility for environmental engineers to expand professional practice into areas such as financial instruments – like insurance or bonds – that may be leveraged to offer a layer of financial security to support increased risks in physical security [8]. Similarly, environmental engineers who work on humanitarian projects such as improving access to drinking water and sanitation in developing countries benefit from an improved understanding of return on investment as they partner with communities who need to make difficult decisions about the types of infrastructure that should be selected to support community health [9].

Lessons learned

The lessons learned through this study include: 1) integrating economics into the environmental engineering classroom provides an authentic context to understand the importance of adopting a systems-level view of the trade-offs inherent as part of the triple bottom line; 2) future work should explore replication of the results in courses offered by other faculty and at other institutions as well as more broadly disseminated results to encourage the adoption of similar approaches in other courses within environmental engineering curricula.

References

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Appendix A. Slides used in CArE 2601 to discuss the answer to the question, “how much would you pay for a sunset?”

Course: CArE 2601

Title: Risk and Sustainability

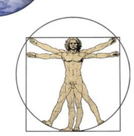
Questions, Announcements, Other

- **IF you have a question, you can be sure that at least one other person has the same question**
  - **SO PLEASE ASK!!!!**
- Any questions from prior lecture, lab, or general (syllabus, assignments, schedule, etc)
- Announcements
  - When’s the next REQUIRED class meeting?
  - When’s the next REQUIRED assignment due?
- Other – ANYTHING?

Review prior lecture Think-pair-share

- Definition of environmental engineering
- Definition of environmental science
- Are ‘all engineers’ = environmental engineers?

Professional Engineers have a professional, ethical obligation to consider the environment (public’s health, safety, welfare)



From google.com

Review vocab due today

- LD50
- Exposure pathway
- Latency
- Oncogenic
- Extrapolation

Optional

- What are the two reasons for risky behaviors?
- What is the ‘precautionary principle’?
  - Do you think it’s a ‘good thing’ or a ‘bad thing’?
  - Pair-and-share

Polleverywhere.com:
Which is a risky behavior?
A) Riding a bicycle
B) Walking to work
C) Enjoying a swim
D) Breathing

What is the tragedy of the commons?

Think-pair-share

Tragedy of the Commons: An Argument Against ‘Free’

“The tragedy of the commons is a dilemma arising from the situation in which multiple individuals, acting independently and rationally consulting their own self-interest, will ultimately deplete a shared limited resource, even when it is clear that it is not in anyone's long-term interest for this to happen. This dilemma was described in an influential article titled "The Tragedy of the Commons", written by ecologist Garrett Hardin and first published in the journal Science in 1968.”

From Wikipedia

Who should pay for the environment?

From google.com

The Time Value of Money: An Argument Against ‘Priceless’

From google.com

So, how do we calculate the '$200' answer?

- See example 6-2 from the text book
- How do we map the example problem to the word problem provided in the required homework assignment (where we calculate lifetime risk of benzene exposure for the nurse)?
- What are the assumptions and how do we document our assumptions?

Quantifying risk (exposure)

- Material (physical/chemical form)
- Exposed (biology)
- Duration/intensity/dose
- Single or multiple materials - synergy

Quantifying risk (exposure)

- Material (physical/chemical
- E (biology)
- /intensity/dose
- Single or multiple ma nergy

chemistry

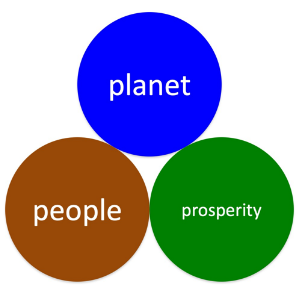
biology

Mass balance

Costs

- Costs of treatment – do you really want to use titanium as the building material for the Golden Gate Bridge?
  - (and won't one form of 'treatment' merely mean that you have some other 'yet-to-be-internalized-cost' somewhere else?)
- Costs of exposure – set to zero?
- Sum of total costs – attempt to minimize?

Which is more important?



From google.com

Appendix B. Instructions for unit in CArE 5605 on modeling transferrable discharge permits.

Course: CArE 5605
Unit: 3 Transferable discharge permits for river water quality
Document: FYI

The objective of this unit is to demonstrate the linkage among environmental quality and economics using an optimization approach with river water quality as an example.

By the end of this units, students should:

1. describe the derivation of the Streeter-Phelps dissolved oxygen sag equations
2. define important physical and biological characteristics impacting dissolved oxygen levels in streams and rivers
3. recognize the use of optimization routines to identify best possible scenarios among alternative options
4. appreciate the application of systems thinking to the evaluation of tradeoffs between treatment and economics to protect water quality

Detailed instructions of REQUIRED exercises (note: All required exercises must be completed before the deadline to earn a grade of 'C'. If you do not complete all required exercises before the deadline, you earn a grade of 'F' for the entire course.)

1) download the file entitled, 'Introduction to Environmental Engineering Chapter 4.pdf'
2) download the filed entitled, 'U 3 required Vocabulary.doc'
3) read **pages 283-320** of Chapter 4 Water Quality Management making notes about the vocabulary terms
4) using your notes, complete the online vocabulary quiz entitled, 'U 3 required vocab quiz' (note: You may retake this quiz as many times as you wish before the deadline. You must achieve a 100% to complete the quiz and earn a grade of 'C' for this exercise. If you do not achieve a 100% before the deadline, you earn a grade of 'F' for the entire course.)
5) follow the links to the, 'required lecture'
6) listen and watch the required lecture
7) complete the online quiz for the required lecture entitled, 'U 3 required lecture quiz' (note: You may retake this quiz as many times as you wish before the deadline. You must achieve a 100% to complete the quiz and earn a grade of 'C' for this exercise. If you do not achieve a 100% before the deadline, you earn a grade of 'F' for the entire course.)

Detailed instructions of OPTIONAL exercises:

1) We will use the optional face to face lectures to work together to complete the optional exercises. To earn credit, you need to complete the optional written homework and submit at the start of the class on the due date for Unit 4 Technology Adoption for Air Shed Protection. BE SURE TO FOLLOW THE FORMATING INSTRUCTIONS!!!

Appendix C. Examples of required vocabulary terms and definitions used to assess student mastery learning in CArE 2601.

Term	Definition
Hazard	implies a probability of adverse effects
Risk	measure of the probability of a particular situation
Risk management	a measurement system used to inform policy decisions
Incremental risk	exposure from high dose for short time is equivalent to low dose for long time
Sustainable economy	one that produces wealth and provides jobs for many human generations without degrading the environment
Renewable resources	that that can be replaced within a few human generations
Non-Renewable resources	that that can be replaced only within geologic timescales
Vulnerable	exposed to and unable to adapt to changes

Appendix D. Instructions for the homework to answer to the question, "how would you exchange transferrable discharge permits to create a low cost solution while ensuring a baseline for environmental services?"

Course: CArE 5605
Unit: 3 Transferable Discharge Permits
Document: Optional Written Homework

INSTRUCTIONS FOR SUBMISSION OF (HANDWRITTEN OR TYPED) HOMEWORK:

a) Use 8.5x11inch paper (no rough edges, no dog ears, no tears from spiral wound notebooks, etc)
b) Place your name, the date, and the title of the document in the upper right hand corner of EACH page (i.e., Dan Oerther, August 31, 2015, Required Written Homework Unit 1)
c) Place the consecutive page number and the total number of pages in the center at the bottom of EACH page (i.e., page 1 of 7, page 2 of 7, page 3 of 7, etc)
d) Staple all pages together in the upper left hand corner

IF THESE INSTRUCTIONS ARE NOT FOLLOWED, THE DOCUMENT IS CONSIDERED UNACCEPTABLE, AND YOU WILL RECEIVE A GRADE OF ZERO FOR THIS ASSIGNMENT.

Construct a model to evaluate the least cost solution for avoiding damage to the Athabasca River from the discharge of pulp and paper mill effluent that considers the 'big picture' as well as 'details'. A maximum score of 100 points is possible for the assignment. A value of 10 points is possible on each of the following ten sections for the report:

1. Providing a narrative of the overall problem and identifying important states and relationships
2. Including the ranges and typical values of states
3. Including a pictorial representation of the system with explicit notation for states and relationships
4. Listing assumptions
5. Using the assumptions to reduce the model to a solvable sub-model
6. Creating a mathematical representation of the sub-model
7. Implementing a solution to the mathematical representation
8. Interpreting the results of the solution
9. Conducting a sensitivity analysis of the solution
10. Describing the lesson/s learned in the overall exercise

Grading Rubric

1. Providing a narrative of the overall problem and identifying important states and relationships
    a. Less than 500 words total
    b. Identify 3-5 states
    c. Identify 5-10 relationships
    d. No grammatical errors
    e. Be sure to explicitly cover the comprehensive areas of people, planet, prosperity, and politics
2. Including the ranges and typical values of states
    a. State references or assumptions to justify values
3. Including a pictorial representation of the system with explicit notation for states and relationships
    a. A minimum of one graph, image, figure, table with a legend/explanation (see Fig 2.2 or 2.3 in INCOSE text)
    b. Some examples may include stretches of the overall river, and unit operations for the treatment plants
4. Listing assumptions
    a. Consider the section 2.9.2.4 'Habits of a system thinker' from INCOSE text
5. Using the assumptions to reduce the model to a solvable sub-model
    a. Preferably using a list form, apply the assumptions to the pictorial model, 3 above, to product a mathematical equation, 6 below
6. Creating a mathematical representation of the sub-model

    a. Select from the range of examples provided in the lecture and supplementary material
7. Implementing a solution to the mathematical representation
    a. Hand-calculation, spreadsheet, or other solution tools are all acceptable
8. Interpreting the results of the solution
    a. Less than 500 words total
9. Conducting a sensitivity analysis of the solution
    a. How does the solution in 8, above, change as the values for different states are changed (i.e., which states have the biggest impact on the overall model outcome, and why)
10. Describing the lesson/s learned in the overall exercise
    a. Less than 500 words total
    b. Consider in the context of section 2.9.2.4 'Habits of a system thinker' from INCOSE text PLUS people, planet, prosperity, politics