Student Learning Outcomes for Humanitarian Engineering Past & Present

At the end of this course, students will be able to:

- demonstrate and apply knowledge of mathematics, science, engineering;
- demonstrate and apply knowledge of the religious, political, moral, historical, economic, and cultural contexts in which technologies were invented and used;
- identify, formulate, and solve engineering problems with understanding and sensitivity to their human and environmental context;
- design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, and sustainability;
- gather and synthesize information about the religious, moral, political, historical, economic, and cultural contexts in which technological problems are debated and addressed;
- conduct research into the history of a technological issue, finding, assessing, analyzing, interpreting, integrating and effectively using essential and appropriate primary and secondary sources, including quantitative and qualitative data;
- function on diverse teams;
- examine issues with a mind open to a variety of reasonable positions and subject their own views to rational criticism;
- present an argument in written, oral, and visual form that displays their knowledge and understanding of the diverse history, culture, social geography, economic considerations, and technical details of a particular technical intervention;
- demonstrate empathy through designing technical interventions that demonstrate an appreciation of ethics, shared humanity, and the diversity of human experience as influenced by culture, race, ethnicity, gender, and class across different times and places.

Link to more course materials, including player roles: https://tinyurl.com/WPIworkshop

Humanitarian Engineering Past & Present: Worcester, Massachusetts, 1885-1899

Course description: This course, an elaborate role-playing experience, places students in Worcester, Massachusetts at the end of the nineteenth century as they explore the complex historical question of what to do about the Blackstone River, heavily polluted after years of receiving sewage and industrial waste from Worcester.

While ample research shows that multidisciplinary and project-based learning has a positive impact on student success and retention rates in science, technology, engineering and mathematics (STEM), experience indicates that it is hard to replicate. In this course you will take on the roles of actual nineteenth-century characters, conducting research using the sources that were available to people at that time, considering both the technical and the human factors affecting this engineering challenge.

Among your various activities, you will investigate several of the most commonly used methods of sewage treatment available at the time (sand filtration, chemical treatment, combined sewerage, separated sewerage) as well as some of the earlier methods (cesspools) that by 1899 were recognized as threats to public health. Depending on the character you are assigned, you may be more inclined to favor the cheapest approach, the approach that will last the longest, the approach most likely to make Worcester an exemplar of advanced engineering design, the approach that will be least disruptive to businesses, or the approach most likely to ensure the just treatment of all residents of Worcester and along the Blackstone River. And while you are charged with arguing for a particular technical approach, your assigned character might also have other motivations: advancing a particular argument about the etiology of contagious disease, seeing that African Americans are employed by the city to build and operate this new sewer system; seeing that the new sewerage system runs through anybody's neighborhood but your own; securing a promise from the city that sewer workers are compensated and treated fairly; ensuring that the city is protected from lawsuits from residents who have become sick from polluted waters; suppressing labor unrest; and so on. You may even be torn by competing interests and forced to make a compromise with your own values. In other words, in this role-playing simulation, as in most actual engineering scenarios, the most obvious technical solution might not be the most desirable because a host of other factors are involved —and after listening to different points of view, you may discover complexities where you hadn't seen them before. People being people, all are motivated differently by these factors. If you won't literally get your hands dirty (this is a simulation, after all), you should expect to experience the messy laboratory of engineering challenges within the context of unpredictable human needs and actions.

Our simulation will take place over three separate game sessions, with homework required of you in between these sessions and active participation during each session and the breaks in between. In the first case, you will take part in a mass meeting held on the Worcester Common in 1885, where residents of Worcester and Millbury gather to compare stories about the human and environmental effects of a noxious river and an overflowing sewer. In the second, you will attend a meeting of the Worcester Common Council as it decides if and how to respond to complaints from its own residents and business owners as well as people from Millbury. In the last, you will once again attend a Common Council meeting, this time as a member of a team presenting a design proposal to mitigate the sewage problem. Here, Worcester's elected leaders will determine how to approach a new mandate to deal with the city's sewage crisis.

Performing well in this course will require a variety of activities and abilities: you will need to learn your character role well, reading the materials provided and seeking out additional sources of information to help you understand your assigned role and character's motivations. You will need to study the questions posed, conduct research, and collaborate with other characters when you think that might be an effective way of meeting your character's objectives. You will need to learn to interpret various forms of data, plot them and present them both visually and in arguments. You will need to write papers and deliver speeches that are persuasive and based on facts available to your character at the end of the nineteenth century. And finally, you will need to understand your character's values and how they relate to the values of other characters, offer alternative or compromise solutions that support the values of a larger community, deal with intransigent differences of opinion, and work within this community to have an impact on the various problems (technical and nontechnical) that arise out of the world you'll be inhabiting in this role-playing class.

Class schedule

Week 1: Introduction to role-playing. Why project simulations? Goals & objectives for course. Introduction to Worcester's industrial history and the role of the Blackstone River. Assignment of roles; assignment of next week's activities. Introduction to library research (aimed at information gathering for next week's session).

Common reading: 1867, Chap. 0106, An Act Concerning Sewers and Drains in the City of Worcester
http://archives.lib.state.ma.us/actsResolves/1867/1867acts0106.pdf
Metcalf and Eddy, *American Sewerage Practice,* Introduction (pp. 1-31)
George E. Waring, "Worcester," in *Report on the Social Statistics of Cities* (1886)
1882 map of the Blackstone River, including the dams and mills south of Worcester
Role-specific readings: see role sheet.

Week 2: First session. 1885, Worcester MA. A mass meeting has been called on the Worcester Commons by *Father Thomas Griffin*, pastor of St. John's Catholic Church on Temple Street. Father Griffin has invited the people of Worcester and the downstream town of Millbury to speak out against the polluted waters of their neighborhoods. Although this is not an official town meeting and no votes will be taken, you are attending for the opportunity to share your views and hear other people's opinions and experiences regarding Worcester's rivers, streams and sewers. In addition to residents who are upset about these polluted waterways and open sewers, you can expect to see political and industrial leaders, doctors and nurses, public health scientists, city engineers, and sanitation workers. Women have no vote in the political arena, but anyone is free to speak at a mass meeting, which levels the political playing field.

Common reading: Arnold Toynbee, "Industry and Democracy" (1881); "Some Sources of Bad Water" (*Scientific American,* July 22, 1876)
Role-specific readings: See role sheet. Using sources published between 1860 and 1885, find out as much as you can about the topic you've been assigned and be prepared to make your case using strong evidence. Use a variety of sources, including technical reports, government documents, and popular accounts. Your feelings are certainly important here —you are trying to persuade people that you deserve consideration for your concerns— but your audience will be most persuaded by a clearly presented combination of passion, facts, and interpretation of your facts.

Weeks 2-3: Students read primary source documents, attend lectures, and do homework and lab assignments to understand the state of late nineteenth-century science and technology, the condition of the Blackstone Canal and Blackstone River, and available approaches to mitigate Worcester County's sewage problem. Individually and in teams, students also work to understand their characters' economic, professional, and personal interests and to form a position on the problem.
Common readings: Metcalf & Eddy, *American Sewerage Practice* vol. 3, ch. 5, "Composition of Sewage."
Annual Report of the State Board of Health of Massachusetts (assigned excerpts);
"Frequent Biological Examination of Water Supply a Necessity," *Fire & Water* (1900).
Role-specific reading: for bacteriological examinations, Metcalf & Eddy, III, 3; for chemical analysis, Metcalf & Eddy, III, 2.

Week 4: Second session. 1885, meeting of the Worcester Common Council. The main item of business on this evening's agenda is to consider how to respond to complaints about the Blackstone River and Worcester's streams coming from residents of Worcester and Millbury. Any resident of Worcester County is allowed two minutes to address the Common Council, which by the end of the meeting will consider a motion and take a vote on how to proceed. Of course you want to be present to state your views and support them, in the hope of persuading councilors to do the right thing. In addition to the elected officials who may propose and vote on motions, you should expect at this meeting city employees (engineers and sewage treatment experts), businessmen and industrial leaders, religious leaders, residents of affected neighborhoods, labor leaders, and anyone with an interest in the outcome of this question.

You may be assigned to a team to present the results of last week's data analysis, or you may be responsible for answering these arguments from data. In any case, your arguments will be based both on the facts available to you in 1885 and your character's primary interests and motives. See your assignment and the rules governing this meeting.
Common reading: Thoreau, "Resistance to Civil Government" (1849)
Role-specific reading: see assignment on role sheet.

Week 5: A change in the legal landscape.
Common Reading: MA 1886, Chapter 331, An Act to Establish a System of Sewage Disposal for the City of Worcester:
http://archives.lib.state.ma.us/actsResolves/1886/1886acts0331.pdf
Metcalf & Eddy, *American Sewerage Practice,* III, 1, "Introduction: Progressive Steps in Sewage Treatment"
Role-specific readings: See role sheet and assignment. You will be assigned to a team that will conduct research on a particular approach and on competing approaches, and you will present your proposed design.
In preparation for next week's session (which again takes place before the Worcester Common Council, but this time in 1896 —ten years after the 1886 legislation), you will learn as much as you can about various means of water treatment: sand filtration, running water, chemical treatment, combined sewer pipes, separated sewer pipes. You will also read and argue from scientific or technical reports to support the claims you make in advancing a particular technological approach; and depending on your character role and assignment, you may also introduce social or economic concerns with credible evidence to support your claim. At this session, Worcester's elected leaders will have to decide how to comply with the court order of 1896, and in the process of debating various technical approaches, they will also have to consider the social challenges attending the different solutions.

Week 6: Third session. 1896, meeting of the Worcester Common Council. Following the court order that Worcester must comply with the 1886 law to clean up its sewage, the Common Council will consider a proposal by Harrison Eddy as well as proposals for other approaches and concerns from a variety of city residents and experts. The large goal is to propose a motion that will be accepted by the Common Council, but the wide array of interests represented at this meeting will likely separate individuals and groups by other goals, and in some cases may even undermine the main goal.

Week 7: Reflections. What were some of the concerns that complicated the technical questions you considered? What ethical choices did you make? If you made ethical compromises —if you ever made an argument against your beliefs, formed an alliance with someone whose values you didn't share, or did or said something you don't quite believe— why did you make those compromises? What factors did you consider in deciding how to act? What new moral issues did you discover along the way, that you didn't see at first? As an objective person —the person you really are rather than the role you played— were you ever troubled by your character's behavior? Were your values tested at any point? What, if any, frustrating stalemates did you encounter? What factors made them difficult to resolve? If you resolved them, how did that happen? If not, what were the deal-breakers? Whether your character won or lost in the main or lesser objectives, did you observe any injustices in the processes or outcomes of this simulation? What were they and why did they occur? What conclusions have you drawn about political processes?

ASSIGNMENT 1: Research your role

1. Research the role you were given. This will be your character identity through the end of our 7-week term.

Read the documents included in your character role packet. Think about how you will achieve your objectives and what you need to learn about your character, conditions in Worcester, the scientific knowledge of the day, etc. Begin to think about how you will play your role.

Find your character in the *Worcester City Directory* of 1885:
https://tinyurl.com/WorcesterDirectory1885

Locate your character's residence and place of employment (if any) using this 1886 atlas of the City of Worcester:

http://archives.lib.state.ma.us/handle/2452/127885 (Links to an external site.)Links to an external site.

Note that the atlas is interactive: you can zoom in at high resolution and move around through the city.

For easier movement throughout the city (in a single interactive image, though it is much less detailed and much less accurate), try this 1878 aerial view of Worcester:

http://maps.bpl.org/id/10182 (Links to an external site.)Links to an external site.

2. Post a screenshot of your character's residence and place of employment (if any) To Canvas Discussion board - PIAZZA

3. **Read this 1867 law**, "An Act Concerning Sewers and Drains in the City of Worcester":
http://archives.lib.state.ma.us/actsResolves/1867/1867acts0106.pdf
Think about how it relates to your character. From your private point of view, is it a good law or a bad law? Why? Is your position complicated, so that in some ways this law advantages you and in some ways it disadvantages you? As you do so, consider where your character is situated on the map in relation to rivers and streams.
Write up your response in not more than 200 words.

A HORRIBLE DISCOVERY!

DEAD BODY Found Floating in the BLACKSTONE CANAL!

Mike Finnegan, grocer at 74 Temple Street, discovered a DEAD BODY in the canal between Temple and Winter Streets.

Male body was bloated, may have been in canal for SEVERAL DAYS.

Who was this man? How did he land in the canal? What were his last hours like?

WHERE IS THE GRIEVING WIDOW?

Does ANYONE at City Hall CARE?

MASS MEETING AT WORCESTER COMMONS

NEXT TIME WE MEET. . . PREPARE TO SPEAK OUT!

Father Thomas Griffin, Pastor, St. John's Catholic Church. Worcester, 1885.

Course Module: 19th-Century Sewage Treatment Processes;
Scientific Discovery and Debate

Reading for class: Leonard Kinnicutt (1890). "Sewage and Sewage Disposal." *Journal of Massachusetts Association of Boards of Health*, pp. 22-48.

Reasons for assigning this reading:

- It contains what was known about the topic of sewage treatment in 1890 and describes the different processes available at the time;
- It was presented at the Massachusetts Association of Boards of Health, and includes a brief discussion after the lecture (thus giving students a view into scientific discussions and the dissemination of new knowledge);
- It offers a window into changing theories (the belief that sewage should be used for fertilizer gave way, with the discovery of bacteria, to the belief "that it is a sanitary duty to get rid of sewage as quickly as possible"; and the end of the practice of emptying waste into rivers);
- It offers a window into controversies within the scientific community (can clear effluent be released into a river, or does the presence of pathogens make that an irresponsible approach to waste management?);
- Students can draw the conclusion that no one single process will be effective in all circumstances, so that engineering must be applied to a context;
- Class roles include the paper's author and several relevant characters (chemists and biochemists employed by the Massachusetts Board of Health and the Lawrence Biological Station);
- Reading introduces the concept of integrated processes;
- Reading introduces numbers (amount of waste generated per capital and by a population of a certain size) that will be needed to maintain mass balance; students will later learn mass conservation to design their own treatment processes;
- Reading contains a process diagram of the chemical precipitation plant in Worcester.
- Homework assignments prepare students to respond, from the vantage point of their character roles, to the treatment process that "Prof. Kinnicutt" will present.

Class lecture: A chemical engineer (David DiBiasio, in the role of Leonard Kinnicutt) describes a typical nineteenth-century waste treatment plant. Lecture illustrates the use of an integrated set of single-unit operations, all with the goal of producing clean water for discharge into the environment. Lecture also introduces the notions of mass conservation, with some numbers illustrating the size of the problem. Lecture includes photographs of late nineteenth-century Worcester sewage processes.

After lecture, students (in roles) challenge "Prof. Kinnicutt" on questions regarding bacteria, the extent of chemical purification, and the effect on downstream communities.

Learning outcomes: to understand the limits of what was known by 19th-century engineers; to understand how engineers and scientists both relied on one another and challenged each other; to put

together an understanding of context (multiple stakeholders) to critically view a process or design; to read critically and debate a question using evidence; to read and understand a technical document; to learn about mass balance and the mathematical calculations necessary to treat a community's waste.

***Note to workshop participants:** if you cannot find a chemist or engineer to deliver this lecture, you can ask the students playing the roles of engineers to develop their own lecture using the materials in the Kinnicutt reading (we can provide 19th-c visuals for them to use in a presentation). We also have a low-resolution video of the lecture, and hope in a year to have a high-resolution video we can make available.

INSTRUCTIONS FOR END-OF-TERM PROJECT

For the final project, you are a member of one of four teams. Each team is assigned one possible approach to solving Worcester's sewage problem.

Team 1. proposal for the Waring plan for separated sewer lines
Team 2. proposal for chemical treatment
Team 3. proposal for intermittent filtration
Team 4. proposal for broad irrigation

As part of the Final Project, your team must present a proposal in the form of a poster and presentation. Everyone on the team must contribute to the project, and during the final class presentation, each person on the team must present for the same amount of time (i.e., no team spokesperson).

Your final Team Proposal Report must include:

5 pages single spaced, not including cover page and table of contents.

1. Cover page

2. Table of Contents

3. Problem Statement

4. Background: Set the historical context. What are the external and internal conditions that are driving the need for this proposed solution?

5. Your proposed solution (recommendation). Address the following considerations:

- Benefits of your design
- Population growth
- Limitations
- Length of time your design will be operational, based on population growth estimates
- Costs

6. Next steps