Integration of Environmental Humanities Modules into the Environmental Engineering Classroom

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Abstract

In today’s rapidly changing world, engineers and scientists are challenged with solving the multitudes of environmental and social problems our society is currently facing. The rapid growth of science, technology, engineering, and mathematics (STEM) research and pedagogy is critical for developing technical solutions to these environmental issues. However, STEM fields are not necessarily oriented towards understanding the cultural, ideological, political, and historical contexts in which environmental problems occur. In this study, both individual and team-based environmental humanities modules (EHMs) were developed for and integrated into an upper-level undergraduate introductory environmental engineering course to bring together concepts of engineering, science, and humanities in the classroom. The goal of this study was to evaluate the impact of the environmental humanities on fostering an increased understanding of the broader context of multidisciplinary environmental engineering work. The overall impact of the EHMs was evaluated through student responses to a survey administered at both the beginning and end of the course. Survey results indicate that the EHMs enabled students to increase their perception of their understanding of environmental engineering and its effect on society’s environmental challenges.

Introduction

As our world continues to evolve, an increase in the development of technical solutions is critical for meeting society’s growing needs. Today, there are many environmental and social problems facing our world. Zero hunger, clean water and sanitation, affordable and clean energy,
sustainable cities and communities, and positive climate action are among several of the 17 Sustainable Development Goals set forth by the United Nations (Fig. 1) [1]. The development of these goals is directly related to several pressing environmental problems that we are currently facing around the world. Science, engineering, technology, and mathematics (STEM) research and pedagogy is critical in finding technical solutions to problems, such as world hunger, clean water and sanitation, and clean and affordable energy. Scientists and engineers excel at identifying and explaining problems; however, they alone cannot solve them. The National Academy of Engineering has categorically stated that today’s engineers need to be more than just individuals who are good at math and science; today’s engineers must also be creative and innovative in working to improve the health and safety of our society. This emphasizes that an understanding of the cultural, ideological, political, and historical contexts in which environmental problems occur is essential to solving our society’s most pressing environmental problems [2-3].

Over the past decade, there has been increased interest in the academic field of the environmental humanities, along with a push to abandon the narrow disciplinary tradition of solving problems [2]. According to Criteria 3, Student Outcome 4 of ABET, the engineering accreditation body, programs should ensure that graduating students have “an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts” [4]. In order to meet these criteria, STEM research and education must turn to the tools, approaches, and sensibilities of the environmental humanities, a field that includes expertise in areas, such as culture, history, and politics [3, 5]. Therefore, in this study, a series of environmental humanities modules (EHMs) were developed for and integrated into an upper-level undergraduate introductory environmental engineering course throughout two consecutive semesters in order to help students cultivate and retain an increased understanding of the broader context of multidisciplinary environmental engineering work.

The course included in this study is a core environmental engineering course typically taken in the third year of the civil and environmental engineering undergraduate curriculum. This course is an introductory-level course to the field of environmental engineering, which covers topics, such as solid and hazardous waste management, air pollution, and sustainability and green engineering. The EHMs were developed for and integrated into this course during the Spring 2019 and Fall 2019 semesters. These EHMs would allow students to explore various environmental issues present in our society through learning about historical events that resulted in major environmental laws and regulations, growth of waste management technologies around the world, and engineering advances in sustainable and green engineering practices, to name a few topics.

The EHMs included a variety of lecture and discussion materials, along with a series of individual and team-based written and oral projects. In the section of the course on solid and hazardous waste management, students were introduced to the history of waste management practices in the U.S. through lecture materials and individual and group assignments and projects. Students were introduced to several major historical events that led to the passing of current waste management laws and regulations in the U.S. Such laws include the Resource Conservation and Recovery Act of 1976 (RCRA) and the Comprehensive Environmental Response, Compensation and Liabilities Act of 1980 (CERCLA), laws that created the
framework for the proper management and cleanup of solid and hazardous wastes in the U.S. At the end of the section, students were required to complete either an oral or a written assignment in which teams (of typically 3-4 students) conducted research outside of the classroom into the history and current practices of solid and hazardous waste management in various developing and developed countries. Project deliverables included addressing the social, political, economic, environmental, and moral implications of the assigned country’s waste management strategies and regulations.

In the section of the course on air pollution, students engaged in discussions on the development of air pollution regulations in the U.S., such as the Clean Air Act of 1970 (CAA), by learning about various devastating air pollution episodes that took place throughout history and the implications of each episode on human and environmental health. Students were also introduced to technologies that have been developed to improve the quality of our air and mitigate air pollution emissions from residential and industrial sources. At the end of this section, students completed either an oral or a written assignment that required teams to conduct research on the degree and state of air pollution in various countries from a global perspective. With such EHM, students were not only exposed to science and engineering fundamentals and technologies, but also to the cultural, political, and historical context behind the innovations we see in these environmental subjects today, which is not always the case in the environmental engineering classroom.

Finally, in the section of the course on sustainability and green engineering, students learned about new and innovative technologies of green engineering that pertain to environmental engineering work. Students also completed an assignment in which they evaluated the impact of the materials and resources they consume in their daily lives on the environment. Students did this by calculating their ecological footprint which measures the ecological assets that they require to produce the resources they consume and to absorb the waste they produce. At the end of the semester, students were also required to complete a final team-based assignment (in teams of 4 students) that included research into the social, historical, economic, and moral implications of various major environmental events throughout the history of the U.S.

In order to incorporate the EHM into the classroom, various course materials were developed. Course materials primarily included: the development of several PowerPoint presentations, the use of YouTube videos, the use of clips from various related movies and documentaries, and the facilitation of open class discussion. Fig. 2 presents a few samples of course material developed through PowerPoint that were used to incorporate the environmental humanities into the classroom. Through the incorporation of such EHM into the classroom, students were exposed to a holistic and critical understanding of the global, economic, societal, and environmental impacts of multidisciplinary environmental engineering solutions.
**U.S. Environmental Protection Efforts**

- **Common Environmental Values:**
  - No adverse effect on our personal health
  - Minimal or no affect on public health
  - Worthwhile to protect species and natural environments
  - Minimize the constraints placed on individual liberties
  - Consider both the costs and benefits of environmental protection efforts

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**Historical Stages of U.S. Environmental Protection Efforts**

- **pre-1945:** Common Law/Conservation Era
- **1945-1962:** Public Works Era
- **1962-1972:** Environmental Movement
- **1972-1980:** Federal Regulatory Era
- **1980-1990:** Refining Regulatory Strategies
- **1990-?:** Regulatory Recoil
- **post-?:** Unknown

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**New Articles from 2016-2017 Reporting Air Pollution Episodes**

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**Love Canal, NY - Superfund Site**

- October 1976: Niagara Gazette reports materials from a chemical landfill have been seeping into basements in the area; people falling ill
- November 1976: Gazette reports chemical analyses of residues near Love Canal indicating the presence of 15 organic chemicals, including toxic chlorinated hydrocarbons (PCBs)
- May 1980: President Carter declares the site a national emergency

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**Waste Management**

A look into the historical and social context of the management of solid and hazardous waste in the U.S.

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**Great Smog of London of 1952**

- Lasted for 3 days – Slowed transportation; increased crime
- Respiratory tract infections (bronchitis, pneumonia, heart failure, etc.)
- 4,000 dead (2,000 more dead in the coming months); 100,000 more fell ill
- Worst air pollution episode in the history of the U.K. – led to legislation to clean air

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**Landmark Hazardous Waste Episodes**

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**Fig. 2.** Sample course lecture material for incorporating the environmental humanities into the environmental engineering classroom.
Methodology

In order to evaluate the impact of the EHMs on student understanding of the broader context of various environmental engineering works, all students enrolled in the two course sections (38 students in Spring 2019; 32 students in Fall 2019) were asked to complete an anonymous survey at the beginning and the end of the semester. The 70 total students who completed the survey over the Spring 2019 and Fall 2019 semesters in this preliminary study consisted of 23 female (~33%), one Hispanic, one African American, and four Asian students. The classes were comprised of 36% transfer students who were enrolled in their first or second semester at the university after finishing two years at various community colleges in the area. This preliminary study did not include a “control” class, as only one section of this course is offered each semester at the university. For all 70 students, this was the first course taken in the field of environmental engineering. Therefore, most students started the semester not knowing what environmental engineering is, what environmental engineers do, or how the field of environmental engineering can affect their daily lives, allowing for a comprehensive sample set for this study.

The administered survey was adapted from the 2000 National Environmental Education and Training Foundation (NEETF) Survey [6]. In the administered survey, students were asked to evaluate a series of eleven statements pertaining to their perceived understanding of environmental engineering, the management of environmental pollutants, and the need for and development of environmental laws and regulations. Table 1 presents the statements that were included in this anonymous survey given to the students at the beginning and end of the course.

Table 1. The eleven statements included in the anonymous, environmental education survey administered at both the beginning and end of the course.

<table>
<thead>
<tr>
<th>Number</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I understand what environmental engineering is.</td>
</tr>
<tr>
<td>2</td>
<td>I understand what an environmental engineer does.</td>
</tr>
<tr>
<td>3</td>
<td>I understand how the management and treatment of solid waste effects my daily life.</td>
</tr>
<tr>
<td>4</td>
<td>I can list specific examples of how federal and state regulations of solid waste management have affected my daily life.</td>
</tr>
<tr>
<td>5</td>
<td>I understand how the management and treatment of hazardous waste affects my daily life.</td>
</tr>
<tr>
<td>6</td>
<td>I can list specific examples of how federal and state regulations of hazardous waste management have affected my daily life.</td>
</tr>
<tr>
<td>7</td>
<td>I understand how the management and treatment of air pollution effects my daily life.</td>
</tr>
<tr>
<td>8</td>
<td>I can list specific examples of how federal and state regulations of air pollution have affected my daily life.</td>
</tr>
<tr>
<td>9</td>
<td>U.S. state laws and regulations for environmental protection meet the demands of current environmental issues.</td>
</tr>
<tr>
<td>10</td>
<td>U.S. federal laws and regulations for environmental protection meet the demands of current environmental issues.</td>
</tr>
<tr>
<td>11</td>
<td>The condition of the environment plays an increasingly important role in the nation’s economic future.</td>
</tr>
</tbody>
</table>
In the administered survey, students were asked to rank each of the eleven statements from the survey (Table 1) on a scale from 0 to 10; 0 meaning that the student strongly disagrees with the statement and 10 meaning that the student strongly agrees with the statement. A response of “NA” indicates that the student was unsure of their response and/or the student had no opinion on the statement. Direct measurement assessment methods were not included in this preliminary study.

**Results & Discussion**

In order to evaluate the impact of the EHMs on fostering an increased understanding of the broader context of environmental engineering work, the anonymous survey (Table 1) was administered to the 70 total students enrolled in the courses (Spring 2019 and Fall 2019) at both the beginning and end of the course. Student responses to each of the statements in the survey were tallied and evaluated for notable trends. The percentage of students who chose each of the four main rankings (i.e., strongly disagree, disagree, agree, or strongly agree) for each statement in the survey is expressed in Figures 3 and 4 (beginning and end of the course survey data, respectively). In Figures 3 and 4, student survey rankings between 0-2, 3-5, 6-8, and 9-10 correspond to the main rankings of strongly disagree, disagree, agree, and strongly agree, respectively. Table 2 presents the average ranking and standard deviation for each of the statements included in the survey administered at the end of the course.

![Fig. 3. Percent student responses to the eleven statements included in the anonymous, environmental education survey administered at the beginning of the course.](image)

Several findings can be deduced from the student response data presented in Figures 3 and 4. Overall, the results of the anonymous survey administered at the beginning of the course (Fig. 3) showed that students generally disagreed with many of the survey statements, indicating minimal initial understanding of environmental subjects and the effect of environmental engineering work on our society. In particular, statements 1 and 2 addressed basic knowledge of environmental engineering work. Survey results indicate that 25% of students began the course with minimal understanding of environmental engineering work. Statements 3 through 8 asked the students to
rank their perceived understanding of the main subject areas included in this course (i.e., solid and hazardous waste management and air pollution). At the beginning of the semester, approximately 65% of the students stated that they disagreed with these statements, indicating minimal initial understanding of these subject areas. Statements 9 and 10 asked the students to express their opinion of the effectiveness of state and federal environmental laws and regulations to meet the demands of current environmental issues. At the beginning of the course, about 88% of the students reported that they disagreed with the statements that environmental regulations meet the demands of current environmental issues. These responses are encouraging as they show that some students were already actively thinking about environmental issues and what they mean for the future of our environment. This thinking could have been drawn from other courses within or outside of the department, from outside work experience, etc.

![Student Survey Results](image)

**Fig. 4.** Percent student responses to the eleven statements included in the anonymous, environmental education survey administered at the end of the course.

The student survey responses at the end of the course (Fig. 4) showed a lot of promise. Assuming a neutral ranking (i.e., 5) from the students as the null hypothesis, average ranking values obtained for each statement of this survey (Table 2) were statistically significant (p<0.05). As seen in Figure 4, at the end of the course, survey results showed that students generally agreed with many of the same survey statements they disagreed with at the beginning of the course. These changes in survey response indicated that throughout the semester, the students’ perceptions of their understanding of environmental subjects and the effect of environmental engineering work on their daily lives positively increased. Comparing results to the beginning of the semester, at the end of the semester, 100% of students stated that their confidence in their understanding of environmental engineering work increased (statements 1 and 2). Additionally, 99% of the students stated that they now agreed with the statements related to their understanding of the treatment and management of waste and air pollution as it effects their daily lives, which is a 64% increase from the beginning of the semester (statements 3 through 8). These results are promising, as the EHMIs integrated into this course aimed to stress the importance of environmental management on our lives and the wellbeing of society and the
environment as a whole. At the end of the course, approximately 38% of the students reported that they disagreed with the statements that environmental regulations meet the demands of current environmental issues, which is a 54% decrease in student response compared to the beginning of the semester (statements 9 and 10). It is not surprising that at the end of the course, approximately 1/4 of the students still disagreed with these statements given the vast number and severity of environmental issues our society is currently facing. Correlations between survey results and grades on group deliverables cannot be made, as the results of the survey were anonymous.

Table 2. The average ranking and standard deviation for each of the statements included in the anonymous, environmental education survey administered at the end of the course.

<table>
<thead>
<tr>
<th>Statement Number</th>
<th>Average Numerical Ranking</th>
<th>Average Ranking</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.3</td>
<td>Strongly Agree</td>
<td>0.78</td>
</tr>
<tr>
<td>2</td>
<td>8.9</td>
<td>Agree</td>
<td>1.08</td>
</tr>
<tr>
<td>3</td>
<td>9.4</td>
<td>Strongly Agree</td>
<td>0.81</td>
</tr>
<tr>
<td>4</td>
<td>8.9</td>
<td>Agree</td>
<td>1.10</td>
</tr>
<tr>
<td>5</td>
<td>9.0</td>
<td>Strongly Agree</td>
<td>1.16</td>
</tr>
<tr>
<td>6</td>
<td>8.8</td>
<td>Agree</td>
<td>0.78</td>
</tr>
<tr>
<td>7</td>
<td>9.4</td>
<td>Strongly Agree</td>
<td>0.88</td>
</tr>
<tr>
<td>8</td>
<td>9.1</td>
<td>Strongly Agree</td>
<td>1.14</td>
</tr>
<tr>
<td>9</td>
<td>6.1</td>
<td>Agree</td>
<td>1.25</td>
</tr>
<tr>
<td>10</td>
<td>6.0</td>
<td>Agree</td>
<td>1.02</td>
</tr>
<tr>
<td>11</td>
<td>9.3</td>
<td>Strongly Agree</td>
<td>1.46</td>
</tr>
</tbody>
</table>

The final statement (statement 11) asked the students if they believed that the condition of the environment plays an increasingly important role in our nation’s economic future. Student responses to this statement were overwhelmingly strong at end of the semester, with 84% of students stating that they strongly agreed with the statement (a 24% increase from the beginning of the semester), indicating that students had an increased perceived understanding of the connection between the environment and the humanities field of economics. Overall, student responses to the survey statements showed that from the beginning of the semester to the end of the semester, students were generally able to understand the lessons on and retain ideas of what environmental engineering is, what environmental engineers do, and how environmental engineering work effects their lives and our society, based on student perspectives. These findings help to validate the need for environmental humanities in engineering and science courses. Currently and in the future, the interconnections between history, ideologies, cultures, and economies will play a critical role in solving pressing environmental problems.

Conclusions & Future Work

The results of the administered survey show that the students who completed this upper-level undergraduate introductory environmental engineering course have an overall increased, positive perception of their understanding of the cultural, ideological, political, and historical context in
which the various environmental problems studied in this course occur. Survey results also show promise for the goal of this study, as well as for future work related to the integration of the environmental humanities into multidisciplinary environmental engineering education. In hopes of achieving a better understanding of the impact of the EHMs on student perception and understanding of the broader context of various environmental engineering work, this study will continue in subsequent semesters and will include comment sections for students to provide examples when responding to various survey statements. Additionally, in future semesters, direct measurement assessment methods (i.e., problem-solving challenges and open-ended assessment questions) will be added to this study.

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