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Mixed Method Approach to Evaluate Sustainability Thinking among the Next Generation of Civil and Environmental Engineers

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Abstract

Millions of young people, as part of a global movement, raised their voices and called for an urgent *action* on September 21, 2019. A major concern in educating the next generation of civil and environmental engineers is to not only have them understand and appreciate sustainability as a core aspect of being an engineer, but also take action, at a personal and professional level. The purpose of the current study was to evaluate civil and environmental engineering students' development of sustainability thinking. For this study, knowledge, attitude, perceived responsibility, and activism are defined as indicators of sustainability thinking. Using questionnaires as an instrument, a mixed method convergent-parallel design was employed to collect and analyze quantitative and qualitative data, concurrently. Over 80% of the students reported that they changed their lifestyle preferences to live more sustainably, because of their learning in the course. Half of the students, who turned their intentions into action, adapted a behavior to conserve water. Although students reported improved awareness, some students identified financial reasons that obstructed their transition to a greener lifestyle. Environmental engineering students expressed greater intent to practice green living, when compared to civil engineering students.

Introduction

Environmental Education or Sustainability Education may have different meanings for people in different disciplines. For civil and environmental engineering education, students should have a clear understanding that the nature of their job is directly affecting the environment and their practices are governed by the code of ethics, which calls on sustainable development. How we teach or train students to develop their engineering skills, becomes an essential tool to nurture sustainability in their future practice, which was recognized as a pressing issue for educators [1]-[3]. Promoting sustainability as part of everyday practice could establish the missing link to enhance environmental attitudes of engineering students [4], [5].

Many empirical studies reported that environmental education, either as a semester course or as a summer program, not only improves knowledge and awareness of environmental issues, in some cases also promotes positive environmental attitudes, behaviors, and values among various student groups, which range between middle school and college [6]-[13]. Muderrisoglu and Altanlar [14] stated that although environmental attitude and intention may improve, the change may not be reflected in behavior to the same degree. Lack of participation in activism towards environmental issues among college students was noted as quite concerning [14].

Along the lines of activism, Yazdanpanah et al. [13] studied young adults' intentions to conserve water. "The students' attitude (the extent to which he/she believes that supporting a conservation water scheme will deliver positive outcomes) was the main determinant of his/her willingness to conserve water" [13]. To further understand the relationship between environmental education and environmental knowledge, Zsóka et al. [12] evaluated the "issue of consumerism in environmental education." They determined that discussing consumerism does "increase awareness of the need for consumption-related lifestyle changes" [12]. Smith-Sebasto and D'Costa [11] stated that internal locus of control, perceived knowledge, and skill reinforce Environmentally Responsible Behavior (ERB).

In addition to the above studies on activism and intention, the effect of one's major proved to be a determinant of pro-environmental behavior. Ewert and Baker [15], Arnocky and Stroink [16], and Bielefeldt [17] have suggested that differences in pro-environmental behavior exist between those who are enrolled in nature based academic programs. Hyde et al. [1], followed by Kuo and Jackson [4], suggest that well-designed environmental curriculum could improve engineering students' environmental attitude. Several others further studied engineering students' growth and development into environmentally conscientious engineers. Kennedy et al. [18] studied civil and environmental streams of engineering students in their second year of undergraduate study, after students have taken several environmental related courses. Although students displayed improved technical knowledge over the course of the study, the students' attitudes toward the environment did not significantly change [18].

Today, we need our civil and environmental engineering students to develop beyond awareness of the problems; students need to be willing to take on responsibility at the personal and professional levels to become "change agents." Due to the impact that engineers can have on promoting sustainable development, it is not only critical, but also mandatory, that undergraduate education train engineers to understand and apply sustainability design principles [19]. The expected environmental engineering student learning outcomes, with regard to sustainability, is articulated in the Body of Knowledge (BOK) and expected to be rigorous and relevant [20]. Practicing in a sustainable manner as an engineer, is no longer just a recommendation, but a requirement per the ASCE Code of Ethics, Canon 1f [21]. Recognition of that need made ABET [22], the accreditation agency for engineering schools, revisit their expected student outcomes in 2017. Two out of the seven revised student outcomes (Criterion3. #2 and #4) are asking for new engineers to develop an ability to recognize the impact of their solutions in global, economic, environmental, and societal contexts [22].

Since sustainability was recognized as an emerging new metadiscipline [2], several educators and institutions incorporated sustainability modules in their courses [23]. Their goal was to help the next generation of engineers "design with natural resources that have very different constraints for a wider variety and greater number of end users" [3]. Bramald and Wilkinson [24] developed a 10-credit intensive module to grow the idea of sustainable thinking beyond the freshman year. Although the module was deemed successful, the authors stressed that clearer messaging about the role of sustainability was needed. In 2010, Bielefeldt documented different methods, such as life-cycle analysis, to introduce sustainability to first year engineering students [25]. There was compelling evidence that the inclusion of a sustainability module encouraged students to consider sustainability in other course assignments, even though they were not explicitly directed to do so [23]. Furthermore, Bielefeldt [23] suggested that early emphasis on sustainability, in civil and environmental engineering, could improve students' perceived value of sustainability.

Generally, we design introductory level engineering courses to increase factual knowledge. Hyde et al. stated that people, hoping for engineering education to change, assume that increasing environmental content make practicing engineers more environmentally sensitive [1]. For a course to change attitudes, and develop environmental concern and activism among students, it needs to be designed specifically for affective learning [4], [5], [26]. Utarasakul [27], Al-Balushi and Al-Amri [28] have mentioned the importance of active learning tools, such as Problem Based Learning or Project Based Learning, and collaborative learning in effectively engaging students in environmental education to achieve the aforementioned student outcomes. To address the relationship between knowledge and activism, authors of this study expected to see the impact of the problem-solving nature of an engineering course designed for affective learning, to have a positive impact on the students' intention and activism towards environment, beyond attitudinal change.

Current Study

Our study examines civil and environmental engineering students enrolled in a required freshmen-level introductory environmental engineering course and compares the change in self-reported environmental knowledge, attitudes, and intentions over a semester-long course. The course is open to students from all academic years. By evaluating these indicators, we are examining the concept of "Sustainability Thinking." To the best of our knowledge, this study is the first to use mixed method convergent-parallel approach to understand civil and environmental engineering students' perceived responsibility (taking ownership of the problem) and activism (committing to and acting on resolving the problem). Specifically, we are interested in understanding self-reported and self-rated responses (i.e., perception) to answer the following research questions:

- (R1) Did students improve their knowledge of historical environmental problems?
- (R2) Did students develop an intention to practice green living?
- (R3) Did students' intention turn in to action?

The primary question that we are seeking to answer is "Does a freshman level introduction to environmental engineering class change anything in the way civil and environmental engineering students report they live their lives? And, if so, how?"

Along with the listed research questions, the study aims to elucidate the impact of the lead author's pedagogy on self-regulated learning and awareness, taking the learning to the next level of critical thinking and action.

Methods

Study Design and Pedagogy

To understand the impact of an introductory environmental engineering course, a mixed method convergent-parallel approach was used [29]. The design consists of two phases: quantitative and qualitative. In this study, both quantitative and qualitative data were collected concurrently. The quantitative section recorded demographic data and asked close ended questions to relate this study with previous literature. Then, the qualitative portion asked parallel, open ended questions to further understand the impact of an introductory environmental engineering course. For this segment we asked for written responses. The two phases are merged in the interpretation/discussion stage, as a narration, of the study. The rationale for this approach was that the quantitative data and the subsequent analysis will provide greater understanding of the research questions. The qualitative data and analysis refine and explain those statistical results by exploring participants' views in more depth.

The study focused on an introductory-level environmental engineering course, Introduction to Environmental Engineering, for undergraduates at Northern Arizona University, a public university in the southwestern United States.

The course focuses on historical ecological, environmental, and engineering problems emanating from human interactions with the environment. Common environmental contaminants, sources and effects, measurements, and pollution prevention and control technologies were introduced over the 16-week semester. One of the course-specific learning expectations is to understand the ethical and professional responsibility of the environmental engineer protecting the health of humans and the environment, both locally and globally, in a sustainable manner.

Two influential trainings have shaped the lead author's pedagogy: American Society of Civil Engineers Excellence in Civil Engineering Education (ExCEEd) practicum and Association of College and University Educators' (ACUE) Course in Effective Teaching Practices. The author's pillars of pedagogy are as follows:

(1) Designing student-centered instruction, focusing on engagement and inclusion
(2) Establishing strong positive rapport with individual students
(3) Cultivating students' intrinsic and extrinsic motivation
(4) Continuing professional development as an educator.

The course was designed by adapting research-based methods of preparing students before the class, engaging them in "active learning" during the class, and encouraging self-regulated learning throughout the semester [30]-[33]. The development of the class preparation assignment was published in a conference paper [34]. Classroom preparation assignments were used to engage underprepared students while creating an inclusive whole-group discussion. The assessment of the pre-class preparation on student engagement and learning has been shown to be impactful [34]. This course included a total of eight assignments over the course of the semester. Three assignments required students to work with peer-reviewed scientific articles on air pollution health impacts, hazardous waste, and ethical case studies. Two assignments tasked students to do mini research: personal water footprint and waste analysis of a fast food restaurant. In addition, three purely pedagogical homework tasks were assigned to develop self-regulation of learning, such as syllabus review, letter to future self, and mid semester evaluation [32]. The class was oriented towards whole group discussions, followed by group activities. Active learning group activities were designed for each week's content. Examples include working with tangram pieces to implement sustainability into traditional engineering design [35]; reading and discussing Mixed Bag in Michigan activity for risk (Appendix A); and completing personal water footprint discussion with advanced questioning activity (Appendix B).

Data were collected in Fall 2016 and in Spring 2017, from two sections each semester taught by two instructors (four sections total). The instructors used the same material, homework, lecture slides and activities, developed by the lead author, for their respective sections. Data collected for this study include responses to an in-class questionnaire that was administered at the beginning of the semester (pre-course) and at the end of the semester (post-course), for each section. A total of 151 surveys were collected in the first semester (pre and post - course), and 136 in the second semester. Data from the two semesters were combined. The average age of the students surveyed was 20.1 years. This included 49 and 43 female students, and 102 and 93 male students in pre-course and post-course questionnaires, respectively. There were 102 and 95 civil engineering majors, and 49 and 41 environmental engineering majors in the respective surveys. Fifty-two percent of the student body were first year, 27% were second year, 12% were third year, and 9% were fourth year students. A total of thirteen students from other majors were removed from the dataset before the analysis. Female students represented 26% of the civil engineering majors and 45% of the environmental engineering majors. Among all surveyed, 94 of the students surveyed lived in on-campus (residence hall or apartment) housing, 52 lived in off-campus apartments, and 18 lived in off-campus houses.

At the first administration of the questionnaire, students were asked to use a nickname that they would remember, to use again at the end of the semester for the post-course questionnaire. The first questionnaire was estimated to take about 15 minutes to complete, was divided into a demographic information section, and parts A through E. Part A (Appendix C) consisted of a series of "Yes/No" questions to determine students' pre-course knowledge of people or events of environmental significance including Rachel Carson, Cuyahoga River, and Yucca Mountain. Part B (Appendix C) of the questionnaire was composed of 24 statements and was used to measure frequency of environmentally sensitive behaviors (e.g., sorting trash, using re-usable shopping bags). Seventeen of these statements were taken from Vaske and Kobrin [36] and Korfiatis et al.[37]. The last 7 statements, B17-B24, were added to Part B. The response on each statement was rated on a 5-point Likert scale: rarely (1) to usually (5). Part C (Appendix C) consisted of "Yes/No" questions regarding students' awareness of their personal habits effecting the environment, and their opinions and outlook on environmental justice (see full questionnaire in Supplemental Data; available online at ascelibrary.org). Part D (Appendix D) asked open-ended questions—adapted from Kennedy et al. [18]—about self-perception of environmental attitude and environmental role models.

The second administration (post-course) of the questionnaire included the same demographic questions and the 4 parts of the pre-course administration. The post-course questionnaire also included a Part E (Appendix D), consisting of open-ended questions that asked students to reflect upon the most memorable aspects of the course, whether the knowledge they gained during the semester impacted their habits, and if so in what ways. Two of the Part E questions were incorporated from Tomsen and Disinger [38].

For each student response (pre-course and post-course), the data from parts A through C were summarized by six scores:

1. An overall "Knowledge/Understanding of Environmental Problems" (KNO) score was computed from the responses to the ten items in Part A, by taking the number of items the student responded "Yes," and dividing by 10 to obtain a proportion.
2. The 24 items in Part B—measuring value or attitude toward environmental behavior—were divided into three "Environmentally Responsible Behavior" scores (K-ERB, V-ERB, and O-ERB), and an "Active Ecological Behavior" (K-AEB) score, as displayed in

Table 1. The prefixes of K, V, and O refer to Korfiatis, Vaske & Kobrin, and Ozis, respectively. The K-ERB and K-AEB scores were calculated as weighted averages and constructed from items B1-B6 and items B7-B10, respectively, using weights derived by a factor analysis of all ten items from Korfiatis et al. [37]. The V-ERB score was calculated as a weighted average, using weights derived by a factor analysis of items B11-B17 from Vaske and Kobrin [36]. The O-ERB score was calculated based on a weighted average of items B18-B24, which were developed as part of this project and calculated for internal reliability. For each of the four scores, a linear rescaling was applied so that in each case the final score is reported on a 1 to 5 scale.

3. An overall "Environmental Striving/Intention" (ESI) score was computed from the responses to the 17 "Yes/No" items in Part C, by counting the number of items for which the students gave the preferred response and dividing by 17 to obtain a proportion.

Each of the six scores is related to one of the three research questions (R1– R3) discussed earlier. The corresponding research questions and scores are provided in Table 1.

Statistical Methods

All statistical calculations were completed using JMP© Pro Version 14.0.0 (64 bit), SAS Institute, Inc., Cary, North Carolina, 2018.

The K-ERB, V-ERB, and K-AEB scales have been shown to have internal reliability. The standardized Cronbach's alpha was calculated for each of K-ERB, V-ERB, and K-AEB scales using the data collected in this study. The O-ERB scale is new to this project, as reflected by the statements B18-B24. A factor analysis for the statements was completed and the O-ERB scale was constructed by weighing each item, using the resulting standardized factor loadings. An assessment was made of the internal reliability of the resulting O-ERB scale.

For each of the six scores in Table 1, data from the pre-course and post-course questionnaires were matched with the student-chosen identifier (nickname), resulting in 76 pairs of matched records (152 responses). Of the remaining 61 pre-course questionnaires and 75 post-course questionnaires, we could not match the responses (136 total). Reasons for this include students who forgot the identifier they had chosen when they filled out the pre-course questionnaire, and students who completed one of the two questionnaires but not both. The primary reason for completing one but not both questionnaires is that a student may not have been enrolled or present in class at the time when one of questionnaires was administered.

Each of the scores from Table 1 was treated as a response variable, and a mixed-effects linear model was used to assess whether the mean score changed from pre-course to post-course. For all variables, an improvement is indicated by a higher score post-course. The statistical model incorporated a random effect for respondent to account for the multiple measurements (pre-course and post-course) on individual students, and a fixed effect for time of questionnaire administration. We also considered incorporating a random effect to assess differences between the matched pair responses and un-matched pre-course and post-course responses. In every case, there was no significant evidence for such an effect, and it was omitted from the final model. Additional factors were included in the model to assess evidence for differences by gender (female or male), engineering major (civil or environmental), year of study (1, 2, 3 or 4), and housing status (on campus, apartment, or house). We considered interaction terms in the model between pre/post and each of the four additional factors listed above, as well as between gender and major. Not all students responded to every question, resulting in a missing score on some response variables for these students. Consequently, the total sample size differed depending on the response variable analyzed.

Table 1. Correspondence between research questions, scores, and questionnaire

Research Question	Score	Number of Items	Questions
(R1)	KNO	10	A1-A10
(R2)	K-ERB	6	B1-B6
	V-ERB	7	B11-B17
	O-ERB	7	B18-B24
	AEB	4	B7-B10
(R3)	ESI	17	C1-C17

Qualitative Method

As for the open-ended questions in Parts D and E, we adapted a technique used by Prunuske et al. [39]. Two engineering researchers from our team, who agreed on a general method of coding, independently coded all open-ended survey responses. After identifying the concepts, themes, and ideas, the responses were categorized and coded based on the chapters or topics covered in the course. For example, if a response included coagulation/flocculation, the response was categorized as water treatment. After the individual coding, researchers compared the findings, and determined that the results were a close match between the two coders, 98% inter-rater reliability (data not shown).

Following Tomsen and Disinger's [38] suggestion, we believe that open-ended questions provided us the opportunity to consider the effect of the course, which was not necessarily measured by the quantitative data. The survey, as an instrument, allowed us to collect data from a greater number of students, as opposed to collecting data through interviews. Because the instrument was tailored specifically for this course, it was more sensitive to document the changes.

Results

Reliability of Derived Scores

Korfiatis et al. [37] report a standardized Cronbach's alpha for K-ERB (environmentally responsible behavior) and K-AEB (active ecological behavior) of 0.69 and 0.63, respectively. The standardized Cronbach's alpha for K-ERB and K-AEB, when applied to the data in this study, was comparable at 0.71 and 0.61, respectively. Vaske & Kobrin [36] report a standardized Cronbach's alpha for V-ERB of 0.89. For the data in this study, we obtained a value of 0.81.

A principal component analysis of the items B18-B24 resulted in just one component having an eigen value greater than one (eigenvalue = 3.50). The overall standardized Cronbach's alpha for O-ERB was 0.83, indicating good internal consistency among these items. When sub-set by gender, pre/post, and major, the alpha value ranged from 0.79 to 0.87, depending on the subset under consideration.

The three measures of environmentally responsible behavior (K-ERB, V-ERB, and O-ERB) exhibit moderate correlation. The correlation between K-ERB and V-ERB was 0.57, for V-ERB and O-ERB it was 0.54, and between K-ERB and O-ERB it was 0.62.

Quantitative Analysis

Table 2 reports the sample size *n*, coefficient of determination (R^2), and *p*-values (two-sided test of equality of mean) for the main effects of pre/post and each of the four predictor variables (gender, major, housing, and year of study) for the fit of the linear mixed model to the six response variables listed in Table 1. Sample size numbers are the combined number of pre-course and post-course responses used in the analysis for the indicated response measure.

Table 2. Relationship between scores and demographics

Measure	*n*	R^2	Pre /Post	Gender	Major	Housing	Year of Study
KNO	208	0.77	<.0001	ns	0.0333	0.0014	0.0008
K-ERB	264	0.80	<.0001	ns	0.0772	ns	ns
V-ERB	268	0.85	<.0001	ns	<.0001	ns	ns
O-ERB	268	0.89	<.0001	ns	ns	0.0504	ns
AEB	273	0.79	0.0002	ns	0.0505	ns	ns
ESI	264	0.81	<.0001	ns	0.0068	ns	ns

*'ns' is used when the *p*-value exceeds 0.10.

Table 3 documents the estimated means and standard errors from each model fit for each predictor variable in the model. For all of the response variables (KNO, K-ERB, V-ERB, O-ERB, K-AEB, and ESI), average scores demonstrated a statistically significant difference (improvement) from pre-course to post-course survey (Tables 2 and 3). For knowledge of environmental items (KNO) measured as a proportion, the increase in knowledge was 0.21 (from 0.44 to 0.65) from pre-course to post-course. For each of the measures (standardized to a scale of 1 to 5) for environmentally responsible behavior, the increase was 0.35, 0.41, and 0.29 for K-ERB, V-ERB, and O-ERB, respectively. The increase from pre-course to post-course survey in the environmental striving/intention score (ESI), measured as a proportion, was 0.09.

Table 3. Estimated means and standard errors (SE) for each predictor variable for each model.

	Pre- / Post-		Gender		Major	
	Pre	Post	Female	Male	Civil Eng	Env Eng
KNO	0.44 (.03)	0.65 (.03)	0.53 (.04)	0.54 (.03)	0.51 (.03)	0.58 (.03)
K-ERB	2.74 (.12)	3.09 (.12)	2.91 (.14)	2.92 (.12)	2.81 (.12)	3.02 (.13)
V-ERB	3.03 (.13)	3.44 (.13)	3.27 (.15)	3.20 (.13)	2.93 (.14)	3.54 (.14)
O-ERB	3.25 (.14)	3.51 (.14)	3.48 (.16)	3.28 (.14)	3.35 (.15)	3.42 (.16)
AEB	2.51 (.12)	2.80 (.12)	2.71 (.14)	2.60 (.12)	2.54 (.13)	2.77 (.13)
ESI	0.62 (.02)	0.73 (.02)	0.69 (.03)	0.67 (.02)	0.64 (.03)	0.71 (.03)

	Housing			Year of Study			
	Apartment	House	On Campus	1	2	3	4
KNO	0.44 (.04)	0.58 (.05)	0.62 (.02)	0.55 (.03)	0.50 (.03)	0.71 (.05)	0.70 (.06)
K-ERB	2.76 (.16)	2.93 (.20)	3.05 (.08)	2.91 (.11)	2.84 (.12)	2.92 (.17)	3.10 (.27)
V-ERB	3.17 (.17)	3.39 (.23)	3.15 (.08)	3.23 (.12)	2.94 (.12)	3.12 (.19)	3.19 (.26)
O-ERB	3.17 (.19)	3.36 (.25)	3.62 (.09)	3.38 (.13)	3.12 (.14)	3.56 (.20)	3.01 (.28)
AEB	2.61 (.16)	2.70 (.22)	2.65 (.08)	2.66 (.12)	2.52 (.12)	2.56 (.17)	2.52 (.05)
ESI	0.67 (.03)	0.69 (.04)	0.67 (.02)	0.68 (.02)	0.63 (.02)	0.70 (.03)	0.71 (.05)

For KNO, we found evidence of one interaction (Figure 1) between pre/post and year of study (p-value = .0013). In Figure 1, there are notable differences in pre-course knowledge scores by year of study, with students in their second year having the lowest average pre-course score. Nevertheless, these second-year students achieved the largest gains in knowledge score from pre-course to post-course.

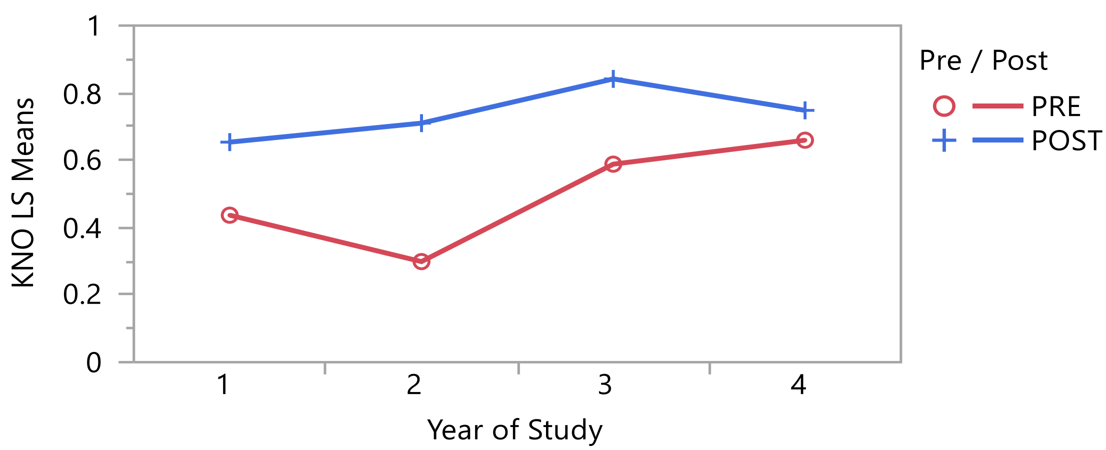
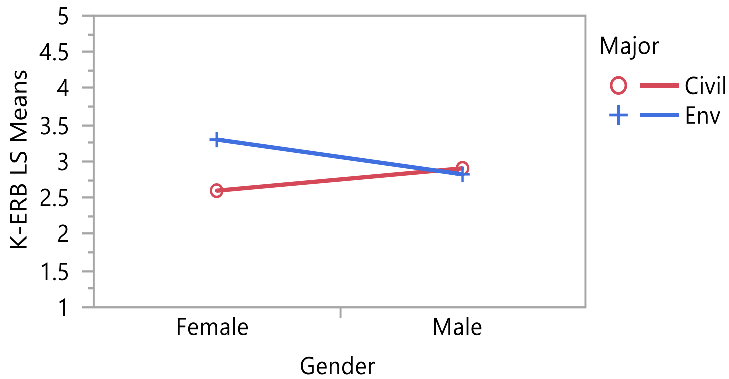


Figure 1. Interaction effects for KNO: pre/post by year of study

For K-ERB, O-ERB, and K-AEB, we found evidence of significant interaction (Figure 2) between gender and major. The p-values were .0013, .0011, and .0206 for interaction with major and K-ERB, O-ERB, and K-AEB, respectively. In Figure 2(a) we see that, on average, males' K-ERB score does not differ by major, while females' average K-ERB score is significantly lower for civil engineering majors than it is for environmental engineering majors. The same pattern of differences observed for K-ERB also plays out for K-AEB, as shown in Figure 2(b), and for O-ERB (not shown here). We note from Figure 3(a) and (b) that, both pre-course and post-course, male environmental engineering students' K-AEB and K-ERB scores are nearly identical to civil engineering students of either gender. Also, Figure 3(a) and 3(b) show the relationship between gender and pre-post scores for K-ERB and K-AEB separately for each major. From these graphs, it is evident that while civil engineering majors of either gender have similar responses, both pre-course and post-course, for environmental engineering majors, females have higher responses than their male colleagues. The same pattern also holds for O-ERB (not shown here).

(a)



(b)

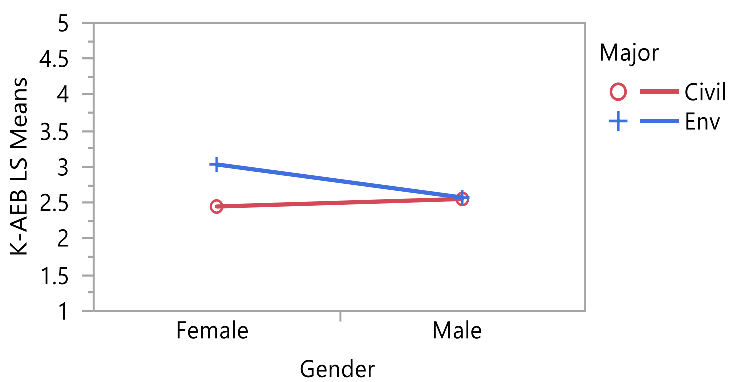


Fig. 2. Interaction effects plots for gender and major: (a) K-ERB and (b) K-AEB.

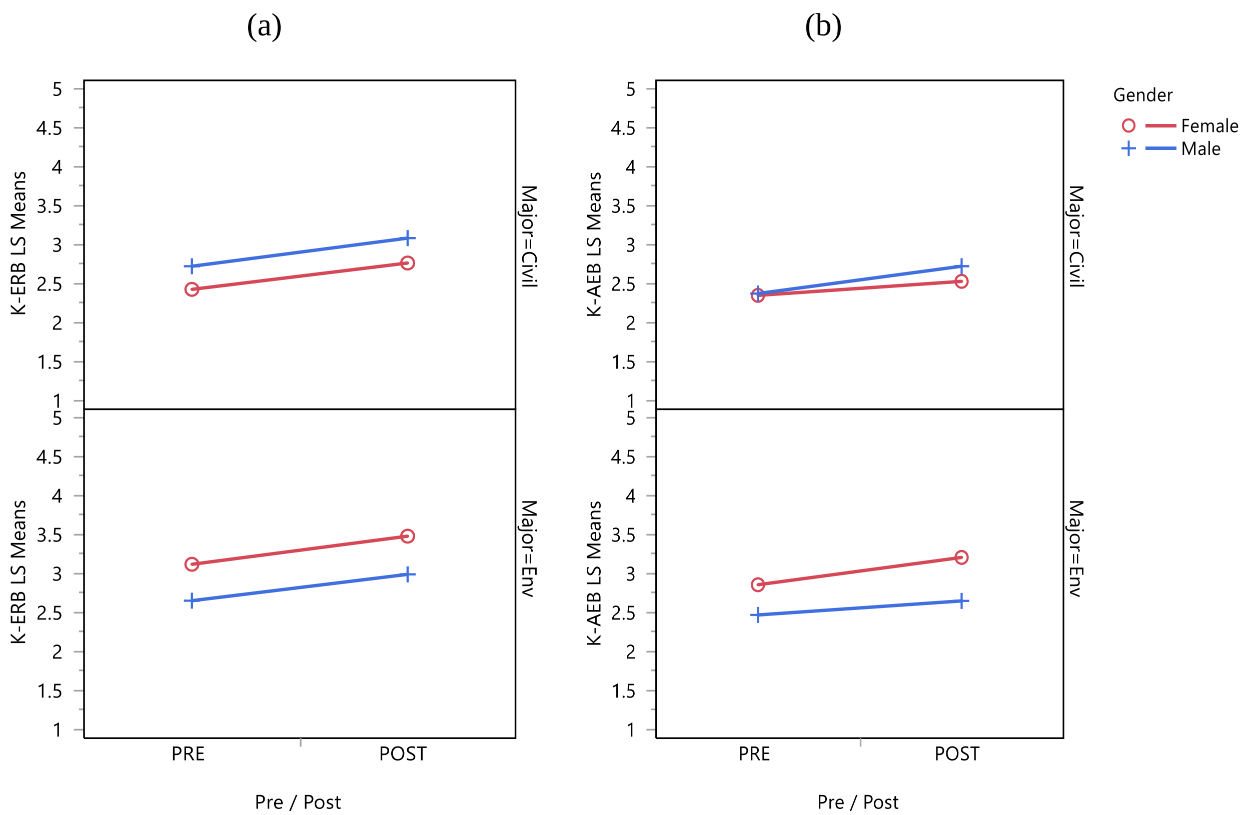


Figure 3. Relationship between gender and pre/post for each major separately for: (a) K-ERB and (b) K-AEB.

Environmental engineering majors scored higher than civil engineering majors on all six response variables. For three of the six response variables (KNO, V-ERB, and ESI), the difference in means was judged to be statistically significant. The KNO average scores for environmental engineering and civil engineering students were 0.58 and 0.51, respectively.

Year of Study differences were apparent for KNO. On average, third and fourth-year students showed the highest average score, and first- and second-year students were essentially tied for the lowest average scores. Looking at the relationship between pre/post and year of study, it is apparent from Figure 1 that while students in all years of study show an improvement of KNO, the improvement is negligible for fourth-year students (from .69 to .73). The magnitude of improvement is similar for first year and third year students (.44 to .65, and .60 to .83 respectively), and largest for second-year students (.32 to .71). Using Tukey's HSD approach for *post hoc* testing for the significance within each year of study group, we found all but the fourth-year students show a significant difference pre/post at alpha = .05.

For one of the response variables (KNO), we found a significant difference based on housing status (Table 2). Examination of the KNO estimated means in Table 3, it is apparent that the significance is attributable to apartment dwellers scoring significantly lower on average (0.44) than both on-campus residents (0.58) and students living in off-campus houses (0.62).

Qualitative Analysis of Free Response Questions

Part D: two questions.

Do you consider yourself to have a positive, caring attitude toward the environment? Give two examples. Why or why not? In the pre-course survey, out of 111 total responses, 86.5% of students responded “Yes,” they do have somewhat positive, caring attitude toward the environment to this question. The remaining 13.5% responded “No.” In the post-course survey, the answers were far more positive with 96% of students answering “Yes,” and 4% answering “No.” The majority of positive responses were explained by recycling, conserving water, and energy, not littering, or enjoying being outdoors. In the post-course survey, students explained their negative responses as follows: “I don’t think before doing something,” and “Not, entirely I do recycle, conserve energy, but for my own personal reasons.” A student responded, “No, I do not care about the environment because for one I don't want to change my lifestyle to please a few trees and animals and two because environmental issues never worry me.” The same student also mentioned “I don't like change, that's why I don't change my lifestyle unless absolutely necessary.”

There was a wide range of examples in how students understood the term “caring attitude towards the environment.” Responses were as follows: “like spending time outdoors”; “picking trash in public”; “not littering”; and “3Rs.” These responses align with the Kennedy et al. [18]. There were more sophisticated answers, such as “I chose this major to do my part,” and “I started a recycling program at my elementary school.”

Name an environmental role model whom you respect the most. In the pre-course survey, 48% of students could name an environmental role model, which is higher than the posttest results of 40% reported by Kennedy et al. [18]. Of those who could name a role model, 94% named an individual, and 6% named an organization. In the post-course survey, 61% of students could name an environmental role model, 10% of whom named an organization. In comparing pre-course and post-course surveys, the proportion of students who could name an environmental role model increased by 13%. Twenty-five out of 70 role model responses, reported as persons, were instructors of this course. Bill Nye and Theodore Roosevelt were reported five and three times, respectively. As recommended by Kennedy et al. [18], this course had strategic guest speakers and visitors during the semester, in addition to introducing non-profit organizations like Water.Org, big media campaigns on issues like Global Climate Change (started with Al Gore then followed by Leonardo Di Caprio), and water scarcity issues (introduced by Matt Damon). All of these individuals were reported as role models more than once. Former teachers, grandparents or parents, and friends were also named as role models.

Part E: Response to post-course open-ended questions.

Question 1: What do you remember most from this course (CENE 150)? Responses to this question varied from paragraph length, including multiple items in the answers, to single word responses. A total of 130 students responded to this question. The common themes in the answers were used to create categories to quantify the responses. Students most frequently reported that they remember their teacher or their classroom engagement (35 responses, 27%).

The next most common response category was concerns about negative environmental impacts and the importance of sustainability, 23 of the 130 responses (18%). The other commonly reported categories were water treatment (21, 16%), air quality or air pollution (18, 14%), water scarcity/usage/pollution (15, 12%), solid or hazardous waste (13, 10%), waste water and sludge (8, 6%) and pollution epidemics and remediation (6, 5%). One student reported “nothing.”

Question 2: What, if anything, do you feel you gained primarily from the course? Six students left this question unanswered, while 122 students responded to this question with answers of varying length. Responses were categorized into common themes. Of the 122 respondents, 93 students (76%) reported that the course provided them with increased knowledge, awareness about environmental issues and sustainability. It was noted that 6 students mentioned their gained learning as “Our impact on the environment,” whereas 14 students mentioned their gain as self-reflection “My impact on the environment.” Seven students (6%) mentioned that they gained a better understanding of how a college-level class works, build teamwork skills, or self-regulated study habits; two students (2%) reported that they gained nothing.

Question 3: Did this course influence you at all to take action and/or live more sustainably? If it did in what ways? If it did not what would you suggest for me to do differently for that purpose? All 122 students responded to this question. For the first part of the question (*Did this course influence you at all to take action and/or live more sustainably?*), 100 students (82%) answered “Yes,” 13 students (11%) said “No,” and 9 students (7%) said they already had a sustainable living style. Common themes that emerged from the positive responses included the following: 50 out of 100 students (50%) reported that they limit their water consumption; twelve students (12%) reported that they “live more sustainably”; eight students (8%) reported that they would reduce, reuse, and recycle more; and 5 students (5%) reported that they would use less energy. One student response was quite notable: “Yes, by being more observant and proactive about the environment.”

Two of the 13 students who answered “No” to the first part of this question provided suggestions for this course to influence students to take action and/or live more sustainably: “Tell us more simple ways of living sustainably or offer extra credit for doing so,” or “Nothing you can do unless you bribe me”.

Question 4: Did any of your preferences, lifestyle, and/or behavior even something very subtle, change at all from your learning in CENE 150? If so, please explain what changed? A total of 120 students responded to this question: 88 students (73%) said “Yes,” 30 students (25%) said “No,” and 2 students said they already had a sustainable living style. Among the students who responded “Yes,” eight students (7%) reported that they have become more aware of their waste production and have begun trying to reduce it. Thirty-eight students (32%) said they conserve water either by taking shorter showers, using water efficient toilets, or using tap water with filter instead of plastic bottled water. Nineteen students (16%) mentioned that they recycle more rigorously, 5 students (4%) said they use reusable mugs, or bags. Three students (3%) bike or walk more, 3 students (3%) changed their diets to eat less meat or became vegan or vegetarian. One student mentioned, “I try to buy eco-friendly products now,” another mentioned “I look at the label of the product every time [now].” A student responded, “I was honestly scared by the facts I learned in this class. It depressed me to the extent that I wanted to drop this class but loved the discussions of the world's largest problems, so I stayed!" One student said, "I keep windows open, and vacuum more."

Question 5: Explain your decision making about what you can or cannot change about your lifestyle, behavior. For this question, 116 students responded, of which 85 students (73%) were open to the idea of behavior change. They reported they were either flexible, or have the ability to change, changed before and can change again. Some of the responses included: "I want to be a part of the change"; "I believe you can change anything if you believe strongly enough in why you're changing"; "One step at a time for longer effect"; "Any small change that I make will directly affect the environment, so I try to do my part"; and "I decided that if everyone says 'my one change won't make a difference' then nothing will change so better start with me."

Six students (5%) reported that there were things they could not or would not change about their lifestyle or behavior. Some answers included, "It is not realistic"; "I can't stop smoking"; "I'll make decisions by myself. A class won't influence that"; "150 minutes a week is not going to change [my] lifestyle"; "Those are just things that I don't pay much attention too"; and "I can change it, but I don't see myself harming anything too much."

Twenty-three students (20%) reported that they could not change their lifestyle or behavior due to lack of control over their decisions, time, and financial constraints, or living in a dormitory. One student mentioned, "It is very difficult for me to take public transportation to/from work/school, so I will continue to rely on my personal vehicle," and "Many of my decisions are based on finances, as long as environmentally friendly products/services are more expensive, I cannot always justify buying them."

Question 6: To what extent are you likely to recommend this course to your peers to help them move towards a more environmentally responsible lifestyle? Students were given a range varied from not likely (1) to highly likely (10). Total post-course survey included 128 student responses for this question. The distribution of responses is shown in Table 4. When the responses were analyzed separately for two semesters (not shown here), there was a clear agreement.

Table 4. Breakdown of responses for question 6.

Score	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Count	1	1	1	0	15	10	29	29	11	31
Percentage	<1%	<1%	<1%	0%	12%	8%	23%	23%	9%	24%

Discussion

Knowledge of Historical Environmental Problems (R1)

As engineering educators, our goal is to train environmental and civil engineering students to understand and apply sustainability principles into their design and to consider for problem solving. In this study, we wanted to know if our "CENE 150: Introduction to Environmental Engineering" course would impact students' knowledge on historical ecological, environmental, and engineering problems. The responses we received from the post-course qualitative questions supported the quantitative results we observed from comparing the pre/post course surveys, which was the students' knowledge increased, even after controlling for differences due to major, housing status, and year of study. Environmental engineering majors had greater overall knowledge and understanding of environmental problems than civil engineering majors, which was aligned with Bielefeldt's findings [17], [25]. This could be that the environmental engineering students took ownership of the information, whereas civil engineering students tend to question why they are required to take the course.

Based on the quantitative results, we observed that students living either on-campus or in a house off-campus had greater understanding, factual, and knowledge scores than students who lived in off-campus apartments, at the end of the course. We believe the qualitative responses to "What, if anything, do you feel you gained primarily from the course?" provide insight to the quantitative results. Two common themes we observed from the qualitative aspect of knowledge gained were "Our impact on the environment" and "My impact on the environment."

The quantitative and qualitative results align with each other, because we believe that the University has an impact on the students as well. The University is located in a city of 71,000 residents and 23,000 university students, of which over half live on campus. The University realizes its impact and strives to do its part for the environment. To reduce the University's environmental footprint, many campus-wide initiatives are in place (e.g., recycling and using reclaimed water); therefore, it makes sense for students who are living on-campus to show increased understanding of the environmental issues, when they are compared to peers living in off-campus apartments. Generally, the off-campus apartments include all utilities in the rental fee, and tenants rarely understand or pay attention to how much of these resources they are using. Based on the students' responses to the qualitative questions 1 and 2 in Part E, the students, in general, have increased their knowledge and improved their awareness in utility use. Campus wide initiatives were beneficial for students, especially living on campus, to see these actions at work and develop a sense of do-ability.

Prior to the analysis, we expected first year students to show greatest growth in knowledge and understanding; however, it was the second-year students that had expressed greatest magnitude in growth. Based on the qualitative data, the first-year students reflected on how the class was managed (i.e., what they remembered the most), which may be due to them acclimating to college life. The second-year students reflected on specific concepts that they learned (e.g., cradle-to-cradle, LD50, six criteria air pollutants, and Love Canal). As described in the quantitative results, it is not surprising that third and fourth-year students had greater knowledge of general environmental problems than first and second-year students. The third and fourth-year students have had greater exposure to environmental related courses. We expected seniors to demonstrate higher scores on knowledge, factual, attitude, and responsibility measures; on the contrary, it was the third-year students who expressed the greatest growth in these variables, possibly grasping the big picture, either by making connections between courses or issues. In this course, the fourth-year students were composed of civil engineering students with international backgrounds, whose learning was driven by communication skill development, based on the qualitative responses.

Intention to Practice Green Living (R2)

Hopefully, as engineering students take on responsibility, they will improve their intent to practice green living. For this to occur, the students need to feel empowered to make changes, starting in their daily practices. One would expect environmentally responsible behavior and active ecological behavior to be aligned and environmental engineering students be more pro-environmental than civil engineering students; these constructs measure pro-environmental behavior. For both of these measures, the pre-course and post-course scores were moderately correlated. All students in the class showed similarity in terms of their environmentally responsible behavior and active ecological behavior scores, regardless of their living conditions, year of study, and gender. Differences between the majors were observed, with environmental engineering majors scoring higher than civil engineering majors. The influence of this course on the students were reflected in their responses, which included "I try to take shorter showers, use public transportation more instead of my car"; "Try to use less disposable items, like plastic and more reusable products"; and "Try to throw away less trash and think about packaging more."

Activism (R3)

Once engineering students are confident of their skills and feel empowered to make environmentally friendly changes, we should observe changes in activism, committing to and acting on resolving the problem. Previous authors' understanding of increased perceived responsibility, increased environmental responsible behavior, and increased active ecological behavior are aligned with increased environmental striving/intention. Yet, intention may not always correlate well with behavior [14]. Quantitative and qualitative questions were asked to evaluate the impact of the course on actual behavior change into activism. We observed significant improvement in active ecological behavior and environmentally responsible behavior scores, from pre-course to post-course. However, we recognized contradictions with behavior. During the personal water footprint exercise, which was reported as the most memorable activity, students needed to time themselves during their shower, and calculate their daily water consumption for washing dishes, flushing toilet, etc. The students were instructed on how to record their time for showering. When we compared the pre-course and post-course responses, for Question 3 in Part C, the average daily shower time was not significantly different. The result may be due to variability in recoding the time. With the trash dump question, the students estimated the amount of trash they dumped each day, with the post-course survey estimations being more realistic than pre-course survey estimations. However, many students did not seem to have a good sense of the trash dumped, because they may have underestimated the amount.

Yet, there is hope that these students will become change agents based on the responses we received to gain insight into students' willingness to make a lifestyle change. Although quantitatively we did not observe a difference in environmental striving/intention scores, change as part of life, no matter how small, was perceived valuable to some students. In personal notes, students documented that they engage in discussions on environmental related issues with friends and family more often because of taking this course. The students mentioned the changes they made, including a variety of activities such as using reusable bags, using mugs, driving less, or becoming vegan. A few statements that showed how students developed their understanding of the course were as follows: "I never used to recycle and now I recycle everything I can"; "I take shorter showers and focus on consuming less as an individual"; and "The clothes I buy, I look into the companies selling them."

Role Model

The course has impacted students' choice of environmental role models. The post-course survey demonstrated that students' role models shifted toward a dominance of course instructors, or people covered in course material. As Smith-Sebasto and D'Costa [11], and Tiesl et al. [40] argued, instructors may serve as a catalyst to improve students' knowledge, attitude, activism, and recognition of role models. In this study, we connect some of the attitudinal changes to the positive influence from the course instructors, as observed in the data. In addition, through personal interactions with one of the instructors, three students in this cohort who started as civil engineering majors decided to pursue environmental engineering as a minor after taking this class.

Limitations

We understand that these results are not to be generalized to the entire civil and environmental engineering students. On the other hand, we understand that implementing active learning strategies, in environmental courses, may help improve perceived responsibility. In turn, the students may improve their activism in environmental causes, not only in their personal lives, but also professional lives. Like McMillan et al. [8], we cannot suggest that the changes in student attitude and behavior in this study will be permanent. To determine the long-term impact of an introductory environmental engineering course, we would need to conduct a longitudinal study through their college years and post-graduation.

Conclusion

In conclusion, we observed students' knowledge of historical problems improved over the course of the semester. Also, intention to practice green living improved as demonstrated in the environmentally responsible behavior and active ecological behavior scores. Environmental engineering students expressed greater intent to practice green living, when compared to civil engineering students. Based on the students' responses for prior experience, the data implied that this course impacted 82% of the students to take action or live more sustainably. Half of the students who took action reported that they limited their water consumption. Upon evaluating gender and major, we observed that female, environmental engineering students' perceived responsibility was significantly greater than the males, in civil and environmental engineering, and females in civil engineering. As a result of their active learning in this course, 73% of the students changed their lifestyle preferences, where conserving water was most common. We acknowledge that the students' sustainability thinking improved as a culmination of pedagogy, self-regulated learning and engagement in multiple class activities as opposed to traditional teacher centered education. Our experience with this study is further supported by Beiler and Evans [42]. Active learning "enhances … student attitudes, and academic achievement" [42]. It is the authors' hope that these changes will be long lasting in the students' personal and professional endeavor. Finally, this study implies that we as educators need to actively engage our students in their learning to promote "Sustainability Thinking".

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Appendices

Appendix A: “Mixed Bag in Michigan” Activity for Risk

Designed by Abdullah Alenezi
Characters drawn by Sara Alenezi

CENE 150 – INTRODUCTION TO ENVIRONMENTAL ENGINEERING
Risk

MIXED BAG IN MICHIGAN
(Adapted partly from USDA PVPCP Epidemiology Course, 1991)

Objectives:
After completing this case study, the students should be able to:
1) Describe the reasons for a toxic organic pollution
2) Describe the environmental impacts of this incident
3) Describe the role of each government agency involved in the case

Directions:
1) You will be working in groups of 4.
2) Read the scenario and the question. Take a minute to think and discuss your answer in your group, and respond as a group.

Part I

In September 1973, a farmer in southwest Michigan noticed a decrease in the feed consumption and milk production of his 400 dairy cows. Within 20 days, feed consumption had dropped by about 50% and milk production had declined from 13,000 lb per day to 7,600 lb per day.

The farmer noted other clinical findings such as increased urination and lacrimation, but rectal temperatures remained normal. Some animals developed hematomas, abscesses, abnormal hoof growth, alopecia, and thickening of the skin. Others developed cachexia and died within 6 months. The farmer and his veterinarian ruled out the usual infectious diseases, but could not diagnose the illness.

Both men suspected something wrong with the feed. Each day, each cow was fed up to 15 lb. or more of 24% protein pellets, plus a mixture of alfalfa and corn silage. Because the local corn silage was low in magnesium, magnesium oxide was added to the grain mixture at the feed plant before pelting. The pellets were supplied by Farm Bureau Services, Michigan’s largest feed distributor and a subsidiary of the state’s most important farmer organization, the Michigan Farm Bureau.

Question: What might you do to determine wether the feed was the cause of the herd’s unusual illness?

Part II

The company denied knowledge of any problems with the feed. Nevertheless, the farmer removed the feed from the main dairy farm, and took it to another farm where calves are raised. There, the farmer gave 12 6- to 18-moth-old heifers and bulls a steady diet of the suspected feed pellets. After 6 weeks, 5 of the 12 animals had died. Interestingly, rats and mice which had long been present in and around the feed storage building were completely eradicated. Autopsy findings of the calves consistently showed liver damage, leading the farmer and his veterinarian to postulate a hepatotoxin as the cause of the mysterious illness.

In early 1974, the feed company began its own feeding trials and chemical analyses. In March, gas chromatography of the feed revealed the presence of an unexpected series of peaks corresponding to the family of polybrominated biphenyls (PBBs). PBBs, marketed as *Firemaster*, were produced as a flame retardant for plastics by the Michigan Chemical Corporation (MCC). This company also sold magnesium oxide under the trade name *Nutrimaster* to Farm Bureau Services, which added the substance to dairy feed. According to MCC, these two products were distributed in the distinctive color-coded bags: Firemaster in bright red and Nutrimaster in bright blue.

The U.S. Food and Drug Administration (FDA), notified of the PBB finding on April 26, immediately initiated inspections of feed mills throughout the state. On April 30, an FDA inspector discovered a half-empty paper brown bag in a Michigan feed mill. Stenciled across the top of the bag was the name, Firemaster. Further, discussions with MCC representatives revealed that they had run out of color-coded bags in spring 1973, so they used plain brown 50-lb. bags for both Firemaster and Nutrimaster. They were distinguishable only by the name stenciled across the top. In May 1973, an estimated 10 to 15 bags of Firemaster were mistakenly shipped to feed mills as Nutrimaster. The Firemaster, similar to Nutrimaster in both consistency and color, was incorporated into feed pellets and sold to Michigan farmers.

The 4 Step Risk Assessment Process

QUESTION 2: Picture yourself as the environmental engineer working for EPA, charged with the responsibility of assessing environmental impact of this toxic organic pollution. In particular assessment of the risk.

In the light of these findings, what kind of study would you recommend to understand the extension of the environmental contamination and the risk associated with it?

Part III

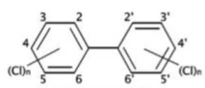
Farm Bureau Services feed containing Nutrimaster was immediately recalled. Shipments of Michigan dairy products outside the state were halted. The Michigan Department of Agriculture began testing animals and dairy products on farms suspected of PBB contamination.

MCC recalled all Nutrimaster on May 2. On May 10, FDA established a farm quarantine guideline of 1 ppm PBB (fat basis) in milk and milk products. On that same date the first farm was quarantined by the Michigan Department of Agriculture based on a level of 34 ppm PBB in milk fat. On May 29 and June 12, respectively, FDA established further quarantine guidelines of 0.3 ppm PBB in animal feeds and 1 ppm PBB in meat fat. (In November 1974, as a result of improved laboratory technology, these guidelines were lowered by FDA to 0.3 ppm in milk, meat, poultry, and dairy products, and 0.05 ppm in eggs and in feed. In October 1977, state law further reduced the limit in milk to 20 ppb.)

The Michigan Department of Public Health (MDPH) was contacted in mid-May 1974, because of concerns regarding possible human health problems on several of the quarantined farms. By that time, approximately 50 dairy and 50 non-dairy farms had been quarantined.

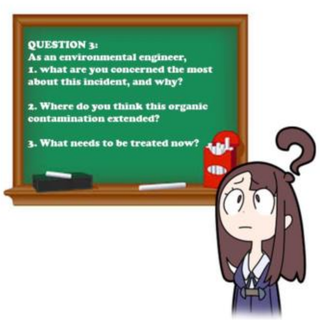
The chemical structure of PBB is analogous to that of (PCBs), with bromine atoms in place of chlorine atoms. At the time of the Michigan problem, relatively little toxicologic information

was available regarding PBB, particularly with respect to human health effects. It was assumed, however, that PBB might have characteristics similar to PCB, perhaps with even greater biologic activity. A prominent feature of PCB and related compounds is their marked tendency to concentrate in fat and hence to remain in tissues for a long time. Human health effects at relatively high doses in occupational exposure settings have been associated with chloracne (a distinctive acne-like skin lesion), and with abnormalities in live, kidney, and peripheral nervous system function. In rats, PCB has been shown to produce hepatic cancer. (Subsequent studies have shown similar oncogenic effects in rats fed PBB.) Other animal studies have suggested that PCB exposure may produce immunologic alterations as well as fetal aberrations and abnormalities in growth and development.



POLYCHLORINATED BIPHENYLS (PCBS)

The first action taken by MDPH epidemiologists, with the help of local health departments, was to interview and examine families living on quarantined farms. By the end of July 1974, interviews in person or by telephone had been conducted with over 90% of both quarantined farm families and other families identified by quarantined families as having consumed produce directly from quarantined farms. In 211 persons, extensive health questionnaire interviews were conducted and samples of blood and urine were collected for clinical laboratory testing (complete blood count, urinalysis, SMA-12). The purpose of this work was to identify patterns of PBB-associated illness and to define the nature and extent of human exposure. It appeared from information gathered that over 250 persons had been exposed on quarantined farms and that about 500 others had also been exposed by eating produce from such farms. No clear patterns of clinical illness were seen.



Part IV

The consequences of the contamination in Michigan have been enormous, since the error went undetected for number of months. As a result, most Michigan residents consumed contaminated milk, beef and other products and some estimates report nearly 90% of Michigan's residents have measurable PBB levels in their bodies[1]. It is noteworthy that nearly 30% of the potential human exposure has already occurred when health problems in livestock were recognized initially in 1974; and 75% of the exposure occurred before the toxicant was identified as PBB[2].

Approximately, 295 (650 kg) of PBB were involved in the incident, of which about 250 kg was fed to livestock; with 50% detected and regulatory actions were taken[2]. It is clear, according to Fries[2], that early detection is much more important for reducing human exposure from a single episode of chemical contamination than is the stringency of regulatory action. More than 500 of Michigan's dairy and poultry farms were quarantined in 1973 and 1974. More than 30,000 cattle, 3,500 swine, 500 sheep and 1.5 million died, and 5 million eggs had to be destroyed. In addition, 788 tons of feed and dairy products also had to be destroyed (3,000 lb. of butter, 34,000 lb. of dry milk).

The State of Michigan has spent (as of a 1987 reference[1]) between $75 to $100 million on PBB cleanup and related expenses. The Michigan Chemical Company settled with the Michigan Farm Bureau Services for $20 million and together the 2 firms settled about 700 claims totaling $40 million. There has also been a $14 million settlement between Velsicol (the parent company for MCC) and the State of Michigan.

Michigan populations represent some of the largest cohorts exposed to polyhalogenated biphenyls (PHBs)[3]. These include about 4000 Michigan farmers exposed during the PBBs contamination incident in 1973-74, over 200 members of farm families exposed to PCBs that were used to line their silos, and about 600 Lake Michigan shoreline residents who ate large amounts of fish contaminated with PCBs. To date, The Michigan Department of Public Health has not found any syndrome or sign of human illness clearly attributable to exposure to PBB. In general, studies of various PHB-exposed populations to date have not shown a clear increase in mortality or cancer incidence although there is some evidence of adverse reproductive outcomes although the effects appear to be small[3].

In addition, to collecting interview and medical record data from members of these cohorts, periodic measurements of serum and adipose PHB levels have been made. These studies of PHB-exposed populations have shown a correlation of blood and adipose PBB and PCB levels with exposure, but as mentioned, no convincing evidence of toxicity due to these exposures has been found[3]. The Michigan department of Public health states that more intensive study is needed to determine if subtle, adverse effects have occurred in members of each cohort or their offspring[3].

Based on longitudinal studies of PBB-exposed Michigan farmers undertaken in 1976-77 and again in 1981-83 by Bekesi et al.[4], the presence of a toxic syndrome related to this chemical has been established. This syndrome is characterized by effects on the neurological and musculoskeletal organ systems in a large segment of the Michigan residents. The low numbers and impaired functions of T lymphocytes observed some 8 years after the onset of PBB exposure in the studied group of Michigan dairy farm residents suggest persistence of a PBB-induced immune deficiency.

QUESTION 4:

1) What was the most valuable thing you have learned from this activity?

2) How can this activity become a better learning experience for the next round?

Appendix B: Personal Water Footprint Activity

CENE 150 – Homework 4
Water Use Inventory- **Estimated Water Use**

These figures are *estimates*. There is a tremendous amount of variation. For example, if you have a *water-efficient showerhead;* the water flow will be about **half** the estimate below. If you have a water-efficient toilet the water used per flush will be as low as 1.5-2 gallons per flush. The amount of water used for tooth brushing, shaving, hand and face washing, and dishwashing will vary significantly based on the time spent and the faucet setting. The amount of water used on yard will vary depending on the area in need of water.

Directions: Create a **PIE CHART** showing your **water use percentages** for each category.

Use	**Conditions**	**Estimated gallons**
Shower	per minute	4-10
Fill bathtub	per use	30-50
Toilet Flushing	per use (flush)	5
Tooth brushing	per minute (letting water run)	3
Washing hands and face	per minute (letting water run)	3
Shaving	per minute (letting water run)	3
Cooking	per meal	3
Washing Machine	depends on setting	20-50
Dish Washing	by hand (per minute)	3
Dish Washing	w/machine (depends on setting)	15-30
Water Lawn	per minute (depends on area)	10-20
Lawn Sprinklers	per minute (depends on area)	5-20
Washing Car	per minute	10
Wash down driveway w/hose	per minute	10
Fill swimming pool	per use	20,000-30,000

Personal Water Use Inventory

For shared activities like washing clothes, calculate your share of the water. For example, if there are 4 people in your house/dorm room and the dish washing machine is estimated to use 30 gallons per load, your share is 30/4 = 7.5 gallons.

Use the data in the first table to fill in the "**Estimated gallons per use or unit of time**," but *change the figures in that column if you have more accurate data about your personal water use.*

Use	Number of uses or time used per day	Estimated gallons per use or unit of time	Estimated gallons used per day	Estimated gallons used per week	Cost per gallon	Estimated cost per week	Estimated cost per year
Shower							
Fill bathtub							
Toilet Flushing							
Tooth brushing							
Washing hands and face							
Shaving							
Cooking							
Washing Machine							
Dish Washing							
Water Lawn							
Lawn Sprinklers							
Wash Car							
Wash down driveway w/hose							
Fill swimming pool							
Other:							

Author's Self-Reflection: Advanced Questioning Techniques "Personal Water Footprint Activity"

I adopted Socrates method for advanced questioning.

I assigned homework for students to track their water footprint over a week. They were given estimates for water use regarding cooking, washing dishes, taking shower, shaving, washing car, watering lawn etc. Students calculated the flowrate of the water through their shower head and find out if they had water efficient shower head. After they tracked their water use and plotted it on a pie chart to see where they use the water the most, they came returned to class.

Using a name picker website, I randomly called on a student. I started by asking: What is the flowrate through your shower head? After going around the room, asking the same question to every other student (33 students total), we obtained shower head flow rates between 0.27 and 4.6 GPM.

Then, I went back to the student who said 0.27 GPM, and asked "The number you calculated compared to the others seems to be pretty low. How would you describe the flow out of your shower head? Does it give you a feeling for full flow or is it just dripping?" She answered that "It feels full". Then I asked the whole class "How can that be possible?" I gave them a minute to think about it; then, the student answered, "Due to aeration at the faucet." We talked about how faucets are engineered to save water. Pressurizing and aerating the water gives you the same fullness feeling without wasting all that water.

On the second round, we started talking about shower length time. As part of the homework, they needed to time themselves and average it out. I went back to the same student, whose name picked by random name picker, and asked her how long her showers were. She said 10 minutes. Then, I went around collected everybody's numbers and tallied them out. At the end, we looked at the range from 4 minutes to 20 minutes)and realized that most people in our classroom averaged about 10 minutes shower time. We talked about how California was promoting 4-5 minutes as optimum time for shower; their motto was "one song one shower".

Then, we talked about "How much water they are using per week? And where they use water the most?" The answers ranged from 176 - 740 Gallons per Week. Student responses included, " I realized I use the water most for washing clothes." Another student said, "My shower makes up 28% of my water use." I posed a question "How does 'cooking' compare to the rest of their water use?" A student responded, "Comparable to the remaining categories." I followed with the question "How do you use water when you are cooking?" A student responded, "Washing the vegetables." Another student added, "You need to wash pots too." I followed up by asking "How about buying triple washed ready to use vegetables?" A student responded, "Well, they still use a lot of water when they are processed at the facility."

Next question was "After doing this analysis and realizing your water use, and where you use the water the most; if you were to change one thing about your daily practices, what would that be? What would you do differently? How would you do that?" The student who earlier said his most water consumption was in "washing clothes" category said, "I wash my clothes 4 times a week, sometimes they are not full loads, I can lower that." Another student said, "I thought about investing in Gray water system to collect the water from the bath and sink to use them for watering the pots."

In the end of the discussion, I asked "What was the most valuable learning they achieved at the end of this activity?" One student said, "[knowing that water is so essential yet so scarce] we are paying so little for water. [The cost of the water per gallon is 4/10th of a cent]." The students in civil and environmental engineering agreed that it starts with them. One student said, "we need to keep it affordable and accessible, but also educate people about the value [of this precious resource]."

Successes: To engage everyone, I asked questions to everyone present in the class. Each student talked at least once during that period. I called on both volunteers and non-volunteers as the discussion progressed. I felt the discussion was lively. Multiple students responded very positive.

Appendix C: Quantitative Section of Questionnaire

Part A: Please indicate your response for the following. [Preferred answer for items in part A is Yes, I know/ I heard]

Rachel Carson
Love Canal
Superfund
Cuyahoga River
Silent Spring
Global Climate Change
Carbon Footprint
Chernobyl
Erin Brockovich

Part B: Please express how often you do the following by referring to the explanation: Rarely (Less than 10% of the chances I could have: 1); Occasionally (In about 30% of the chances I could have, 2); Sometimes (In about 50% of the chances I could have, 3); Frequently (In about 70% of the chances I could have, 4); Usually (In about 90% of the chances I could have, 5). Preferred answer for all questions in Part B was usually [5].

B1. Avoid unnecessary consumption of energy (electricity, gas etc.)
B2. Avoid unnecessary consumption of water
B3. Go shopping with bags from home (use reusable bags)
B4. Use public transportation instead of private car
B5. Avoid buying products with a lot of plastic and useless packing
B6. Drive only if absolutely necessary
B7. Contribute time or money to an environmental group
B8. Engage in environmental action
B9. Save cans, bottles, or paper for recycling
B10. Specifically avoid using products harmful to the environment
B11. Tried to learn what I can do to help solve environmental issues?
B12. Talked with others about environmental issues?
B13. Tried to convince friends to act, responsibly toward the environment?
B14. Talked with parents about the environment?
B15. Joined a specific community clean-up effort
B16. Sorted trash to separate non-recyclables from recyclables
B17. Conserved water by turning off the tap while washing dishes/brushing teeth etc.
B18. Avoid using bottled water.
B19. Try to think twice before shopping to buy things I really need
B20. Shop locally
B21. Avoid using products that are designed to be thrown away after one use.
B22. Try to recycle e-waste (e-waste: old electronics, TVs, computers, monitors etc.)
B23. Try to use my own reusable mug for coffee
B24. Avoid washing my clothes unless I have a full load

Part C: Please answer either Yes (1) or No (2) to the following questions. Preferred answers were provided in Brackets.

C1. I have taken a course in which sustainability was discussed. [1]
C2. I know how much water I use per day. If Yes, I use ________ Gallons of water per day. [1]
C3. I know how long my showers are. If Yes, my average daily shower is ______ minutes. [1]

C4. I like tossing dirty disposable plates into trash after use, because it saves time for me. [2]
C5. I buy stuff just because they are on sale. [2]
C6. I have energy saving bulbs at my place. [1]
C7. I upgrade my electronics/cell phone/computer when the next generation come out. [2]
C8. I know how much trash I dump each day. My average daily trash is ________ Lbs. [1]
C9. I pay attention to the product label when I am shopping. [1]
C10. The fact that a product is environmentally friendly is a determining factor in my purchase decision. [1]
C11. I specifically use cold water for my laundry. [1]
C12. I hold on to a recyclable item and only discard it when I find a recycle bin. [1]
C13. I believe that people should respect the lives of animals and plants because they are part of the environment. [1]
C14. I buy environmentally friendly products even if they are more expensive than conventional ones. [1]
C15. I believe that people – even those I don't know – should be treated with equality and justice. [1]
C16. I spend time in nature. [1]
C17. I'd change at least one thing about my lifestyle if I knew that would make a difference in environmental problems we are facing. [1]

Appendix D: Qualitative Section of Questionnaire

Part D: Please answer short answer questions below:

1. Do you consider yourself to have a positive, caring attitude toward the environment? Give two examples why or why not please:
2. Name an environmental role model whom you respect the most?

Part E:

1. What do you remember most from this course (CENE 150)?
2. What, if anything, do you feel you gained primarily from the course?
3. Did this course influence you at all to take action and/or live more sustainably? If it did in what ways? If it didn't what would you suggest for me to do differently for that purpose?
4. Did any of your preferences, lifestyle, and/or behavior even something very subtle, change at all from your learning in CENE 150? If so, please explain what changed?
5. Explain your decision making about what you can or cannot change about your lifestyle, behavior.
6. To what extend are you likely to recommend this course to your peers to help them move towards a more environmentally responsible lifestyle?
   [1: not likely 2 3 4 5: Neutral 6 7 8 9 10: Very Highly Likely]