Introduction to Air Resources – Just In Time!

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Abstract
This paper describes one of four curriculum modules that are used in an introductory environmental science and engineering course taught at Humboldt State University. ENGR 115: Introduction to Environmental Science and Engineering focuses on a resource approach to environmental management, with modules on air, land, water and energy resources. Blackboard® is used to assist in the course delivery. One of the course goals is to increase confidence in environmental engineering and environmental science majors via hands-on projects, case studies and active learning. The air resources module is taught over a three-week period in a fifteen-week semester. The module curriculum is delivered over 6 lectures and two 3-hour laboratory periods. This paper describes the lectures, labs and out of class activities. The pedagogical approach incorporates web-based teaching strategies including Just-in-Time Teaching (JiTT), developed by physics instructors and used by many different disciplines. After completing assigned readings, the students take online quizzes that summarize these readings. The lecture period is used to clarify misconceptions that were discovered in the students' responses to the online quizzes as well as present new material, using the JiTT approach. Air resources lab activities include an air resources allowance-trading auction, the determination of the ventilation rate of a student chosen enclosed space using a CO_2 meter, and the measurement of CO levels from the campus fleet of vehicles. The curriculum development project is partially funded by a NSF Course, Curriculum and Laboratory Improvement (CCLI) Grant Award 0127139. The curriculum that is available for download at http://www.humboldt.edu/~eae1/CCLI02/ includes reading assignments, online quizzes, laboratory activities and selected portions of PowerPoint presentations.

Course Description
Engineering 115: Introduction to Environmental Science and Engineering is a required introductory course for both Environmental Resources Engineering students and Environmental Science students at Humboldt State University (HSU), with between 60-75 students enrolled each semester. The course has two 50-minute lecture periods per week where all students meet together and a three-hour laboratory period with 24 students in each of three lab sections. The lecture periods are more of a recitation period, as they are interactive sessions, rather than a traditional lecture.

The course includes critical analyses of problems from both engineering and science perspectives through case studies in air resources, geotechnical resources, water resources and energy resources. The course integrates lecture, discussion, student projects, computer labs, wet labs and outdoor field labs in the context of environmental engineering and science students working together on resource management issues.

Students are introduced to a number of problem solving and research skills, including using the Internet for research, web page design, word processing, data collection using field instruments, and data analysis using spreadsheet modeling and Geographical Information Systems. Students are expected to take this course their first or second semester on campus and the only requirement is a co-requisite of college algebra.

A key component of this curriculum is the use of the online quiz aspect of the Just-in-Time Teaching (JiTT) approach, which blends web-based preparatory assignments with classroom learning. The JiTT strategy has been pioneered by physics faculty and has been used by faculty at more than 50 institutions across the country[1]. Two of the documented benefits of the JiTT approach are increased attendance and decreased attrition[2,3].

Once a week, students complete the web-based JiTT quizzes on Blackboard up to an hour before the class that will address the topic occurs. The instructor reviews the responses "just in time" for class and adjusts and organizes lessons based on those student responses. Students come to class motivated to cover the given topic as they know their comments and questions from the JiTT quiz will be addressed in class. The instructor then spends class time addressing students' misconceptions communicated in the quizzes, rather than lecturing on material students have already grasped.

Air Resources Module

The air resources module consists of reading assignments, lecture topics, JiTT quizzes and responses, air quality data collection and analysis assignments, and an air emissions trading simulation. Supporting materials (including PowerPoint slides) can be found at the CCLI project website[4]. Each component of the curriculum is described below.

Readings

Students are assigned readings from Henry and Heinke's *Environmental Science and Engineering*[5]. They also are provided articles and web pages to read. Table 1 below summarizes the topics and related readings.

Lecture Topics and JiTT Quizzes

The air quality module is taught over a three-week period with two 50-minute lectures each week. Table 2 below summarizes a potential list of topics that have been addressed over the three-week period in the lecture periods and the JiTT quiz topics. Due to the nature of JiTT pedagogy, the students drive the specifics of what is discussed in lecture periods and each semester the focus has been different in terms of the details of coverage in the course. Likewise, JiTT quiz topics vary as a result of answers to previous quizzes and questions raised in lecture periods. The CCLI Project Website[4] has the corresponding PowerPoint slides and example quizzes for each of these lecture topics.

Table 1: Reading Assignments for Air Resources Module

Topic	Textbook[5]	Website	Article
Introduction to Air Pollution, Effects of Air Pollution, Sources of Air Pollution,	Pages 492-517	World Resources Institute[6]	
Criteria Pollutants		EPA[7],	
Control of Air Pollution, and Air Pollution Control Cost	Pages 521-548	EPA[8]	
Prediction of Air Pollutant Concentrations	Pages 548 - 559	Shodor Education Foundation[9]	
Ideal Gas Law and Unit conversions	Pages 171-172		
Emissions and Allowances Trading		Leonardo Academy Inc.[10], EPA[11], EPA[12], EPA[13], EPA[14]	
Indoor Air Quality		UT at Austin newsletter[15], Princeton Analytical Laboratory[16], CDC Agency for Toxic Substances and Disease Registry[17], ASHRAE Homepage[18]	Scientific American Article[19] and Lab reading[4]

The JiTT quizzes generally have a calculation question, a conceptual question and a feedback box. Students' efforts are graded based on the how clearly their thought processes are explained. Students receive full credit for incorrect answers if they clearly explain their assumptions and their process. Students that provide correct answers without a clear justification receive no credit.

As shown in Table 2, the JiTT quizzes for the air quality module address the key concepts that underlie the topics of indoor and outdoor air quality. Table 3 below provides several examples of questions asked in the air resources module JiTT quizzes. Details of how JiTT is used in this course to address students' specific misconceptions within the air quality module are described in [20], [21].

Table 2: Lecture Topics for Air Resources Module

Topics	JiTT Quiz Topic
Outdoor Air Resources: Criteria Pollutants and Clean Air Act	Criteria Pollutants and regulations applied to indoor and outdoor air quality
Indoor Air Resources and ASHRAE standards	Estimates of volume of air breathed
Ideal Gas Law and Units Conversions	Unit Conversions (ppm to $\mu g/m^3$)
Atmospheric Processes	Inversions
Emissions: Controls and Models	Gaussian plume modelsControl Technologies
Allowances Trading	Connection between air quality and energy resource use efficiency

Table 3: Just in Time Teaching Quiz Questions for the Air Resources Module

Topic	JiTT Questions
Indoor Air Resources and estimates of volumes	*In your reading of the Scientific American article[19], the authors reported on exposure to chloroform while in a steamy shower. How much (grams) chloroform do you inhale in your average shower?*
Indoor Air Quality and Unit Conversions	*Based on OSHA's recommendations of 50 ppm over an 8-hour day/ 40-hour work week[17], is the exposure to chloroform reported in the Scientific American article a concern to you?*
Outdoor Air Resources: Criteria Pollutants and Clean Air Act connection between air quality and energy resource use	*The authors of your text[5] suggest electric heating as a means to reduce air emissions. Do you think this is a good suggestion? Explain your answer.*

Data Collection and Analysis Assignments

During the 3-hour laboratory periods, students use CO_2 meters to determine the ventilation rate of a space of their own choice. They are provided a website and readings (available at the project web site[4]) that explain the use of the CO_2 meters, the proper data collection methods, as well as describe the use of regression to determine the ventilation rate of their chosen space. Students are encouraged to choose rooms on campus where they have experienced discomfort that could potentially be linked to air quality. Every semester one group of students chooses to determine the ventilation rate of a car with its windows rolled up and discuss the effects of CO_2 build up in an enclosed vehicle. The introductory students learn how to use spreadsheet software to analyze data and calculate a ventilation rate via a linear regression analysis. Students are invited to compare their results to existing indoor air quality standards for $C0_2$ and ventilation rates specified by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) and the American National Standards Institute (ANSI). ASHRAE Standard 62-1999,[18] "Ventilation for Acceptable Indoor Air Quality," specifies minimum ventilation rates and indoor air quality that will be acceptable to human occupants.

Figure 1 Humboldt State University Environmental Resources Engineering Students Caroline Crockett and Noah Walker calibrate their CO_2 meters for their Introduction to Environmental Science & Engineering Laboratory.

In addition, in some semesters, students use CO meters to monitor the emissions of the vehicle fleet at HSU. This assignment currently provides no opportunity for analysis, however the students do benefit from observing first hand the differences in emissions from newer and older cars, vans, trucks and busses. This emission information is made available to the university fleet manager. This activity could be easily extended to include data analysis and the development of a management plan for minimizing CO emitted by the fleet vehicles, however time does not permit this analysis in this particular course.

Air Emissions Trading Simulation
Students participate in an Air Emissions Trading simulation modeled after EPA's SO_2 Emissions cap and trade system created in 1990 under the Acid Rain Program.[22] This simulation is a modification of a simulation developed by the Air & Waste Management Association.[23] Students are put in groups of 3-4, where each group represents a public utility or "company" and has specific pollution emissions characteristics. Each company emits a different amount of pollution. The objective of each company is to be as profitable as possible. The instructor acts as the EPA and sets a limit on the total emissions that are "allowable" in a given year. The emissions limit is the same for each company in any year, but may change (increase or decrease) from one year to another. The companies then make a series of decisions regarding purchasing technology to reduce their emissions, purchasing allowances for emissions or putting excess emission allowances up for auction. The instructor guides the students through the auction process over a time period of 3-7 years depending on available class time. Students keep track of their allowances purchased and sold and their income or expenditures. The CCLI Project Website[4] has the corresponding handouts, worksheets and URLs used in this simulation.

At the end of the simulation, the instructor facilitates a discussion comparing the varying strategies of the groups and where each company started and ended in terms of pollutant emissions and expenditures. The students then go online to the EPA website[14] that documents the results of recent auctions to research the current price of an allowance and follow-up on further questions regarding the cap and trade program. A guided discussion of the costs and benefits of the cap and trade program serves to wrap up the Air Resources unit and often ends with the discussion of issues of environmental and social justice in regulation and management of air resources and the roles of engineers and scientists in this venue.

Observations
As the CCLI project is still in progress, we do not report formal assessment data at this time. Below are observations after the first three semesters implementing this curriculum in ENGR 115: Introduction to Environmental Science and Engineering.

Instructor Observations
One of the challenges introductory environmental science and engineering students face in this course is becoming comfortable with the use of units and units conversions. The air quality module contains some of the more difficult conversions (e.g.$\mu g/m^3$ to ppm using the Ideal Gas Law). Via course readings, online quizzes and the data analyses, students gain insight into the importance of units as well as confidence in their ability to apply those units in critical analyses. Students work very hard on the conversions. Less than 10% of the class is able to complete the conversion from ppm to ug/m^3 when asked to do so in the JiTT quiz and a very high percentage of the class (80-90%) is able to correctly complete such a calculation on the mid-term or final exam. In the most recent semester, a problem requiring a unit conversion was not on the exam.

When asked to reflect on the exam and provide a calculation problem they were prepared to do that had not be covered, approximately 50% of the class wrote out a conversion problem using the Ideal Gas Law.

Student Comments

The indoor air quality portion of the curriculum is particularly well received by introductory students, as they can see the direct impact on their own health. Most students have not thought about indoor air quality in detail and express curiosity and surprise with what they learn in the course.

Students rank the indoor air quality lab as one of the top two out of ten lab experiences. The students enjoy the hands-on opportunity to collect air quality data as well as the opportunity to conduct an analysis for a place on campus and compare the results to existing health standards. Students are clearly engaged in this unit. In one semester, the students self-organized donations amongst themselves and participated in the EPA SO_2 allowance auction. Their bid was not successful, but their participation was.

Summary and Conclusions

This paper summarizes the curriculum for the three-week air resources module used in Introduction to Environmental Science and Engineering at Humboldt State University. The curriculum should be useful to teaching introductory courses to these majors, or those that teach air quality courses. The curriculum utilizes some Just-in-Time Teaching approaches, as well as a data collecting and analysis activity and an emissions trading simulation. The air quality module has been very well received by students. Supporting curricular materials can be found at the CCLI project website[4].

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