AC 2012-3143: A HANDS-ON EXPERIENCE IN AIR POLLUTION ENGINEERING COURSES: IMPLEMENTING AN EFFECTIVE INDOOR AIR POLLUTION PROJECT

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Abstract

Many undergraduate environmental engineering programs have courses on air pollution engineering; however, most of these courses do not include a hands-on learning experience. This shortcoming can influence ABET accreditation since the Environmental Engineering Program Criterion (Criterion 9) states that students must have an ability to conduct laboratory experiments, critically analyze, and interpret data *in more than one major* environmental engineering focus area, e.g., air, water, land, environmental health. Additionally, ABET outcome "b" states that graduates will develop the skills necessary to plan, design, execute, and critically interpret results from experiments. Students in the Environmental Engineering Program at the United States Military Academy have water-related laboratory experiences in lower-level courses, such as jar testing and biochemical oxygen demand experiments, similar to those found in many undergraduate environmental engineering programs at other universities. This work presents an indoor air pollution project that provides students an opportunity to develop and test a hypothesis related to an indoor air quality issue that interests them. The methods and materials required to implement this educational experience in environmental engineering programs to meet ABET accreditation requirements are also presented. Preparation for the project requires student teams (3-4 students) to develop a basic evaluation and sampling protocol to test a potential indoor air pollution problem. Students identify a pollutant of concern, either a gas (CO, Cl, VOC, Radon, O_3, etc.) or particulate matter, and identify a feasible and safe location on campus for testing. Student teams are required to submit a 5-page technical report on their methods and findings and must compare the concentration of pollutants they detect to the Permissible Exposure Limits (PEL) for occupational exposure to indoor air pollutants established by the National Institute for Occupational Safety and Health. Students receive feedback on their protocols and results from their customer, their instructor, and the environmental engineering lab manager.

(1) Introduction

Undergraduate environmental engineering programs should equip their students with the basic foundations in the discipline. Additional "significant experiences" are required to help students develop a more holistic appreciation for professional practice issues and to prepare them for the workplace.[21] Such experiences should relate course material to professional practice; be commensurate with a student's skill level according to their progression through a curriculum; and, should not be perceived by students as being redundant. Examples of such experiences include: field trips; hands-on laboratory exercises; field sampling; modeling; technical designs; experimental designs; independent laboratory research projects; and research papers.[6] Much of the critical thinking skills described in Bloom's taxonomy can be accomplished via laboratory experiences.[18,23] The objectives of lab experiences include[15,23]: instrumentation, experiment, data analysis, design, learning from failure, creativity, communications, teamwork, and ethics. All ABET accredited programs must provide evidence that their graduates have attained the 11 ABET Outcomes (a-k). The ABET Outcome "b" states that graduates will develop the skills necessary to plan, design, execute, and critically interpret results from experiments (ABET). In addition, the ABET environmental engineering program criteria (Criterion 9) states that students have an ability to conduct laboratory experiments and to critically analyze and interpret data *in more than one major* environmental engineering focus area e.g. air, water, land, or environmental health (ABET). Many environmental engineering programs provide a laboratory experience in the water and biology focus areas e.g. jar testing and biochemical oxygen demand experiments.[7] Although the water focus area is a stimulating and important area of environmental engineering, longitudinal survey data (not shown) of our graduates suggest that students seek knowledge in the other focus areas as well. This work presents a junior level indoor air pollution (IAP) laboratory that provides students with an opportunity to develop and test a hypothesis related to an air quality concern that interests them. An assessment of hands-on air quality experiences at other institutions is also presented. Finally, an approach for integrating hands-on air quality experiences into a course is offered.

(2) Background and Applicability to ABET Accreditation

During academic year 2008-2009, the faculty in the United States Military Academy (USMA)'s environmental engineering program introduced an IAP project for the undergraduate air pollution engineering course. Before 2008, the course concentrated largely on ambient air pollution control with only one lesson dedicated to IAP. The lesson discussed the sources of common indoor air pollutants and reinforced material balance concepts taught in other courses by applying them towards an IAP scenario. Realizing that an IAP control project could strengthen program support for ABET criteria and outcomes, USMA's environmental engineering faculty decided to expand IAP coverage and strengthen the students' ability to plan, design, execute, and critically interpret results from experiments. Two newly revised lessons were devoted to the topics of IAP sources, material balances, and controls. The lessons discussed how IAP poses significant issues to human health and how it is often underemphasized in comparison to ambient air pollution. Cooper and Alley (2011) states that many people spend more than 20 hours per day on average in an indoor setting. Since the course is the only air pollution course offered in the our curriculum, the aim of this assignment was to broaden the students' knowledge of other environmental engineering focus areas while supporting the program's major concepts and themes, as well as the ABET outcomes.

Table 1: Universities that offer courses with a hands-on indoor (I) or outdoor (O) air quality experience. Some of these courses are offered outside of the environmental engineering program. Examples of air quality parameters that have been quantified in these laboratory exercises are provided for selected programs. This table is not an exhaustive list of programs that offer a hands-on experience.

School	ABET EAC Accredited Program?	Undergraduate (U), Graduate (G), and/or Cross-listed (C) Course	Air Quality Parameters
Drury University	NO	U	Not provided.
Georgia Institute of Technology	YES	U&G	PM
Missouri University of Science & Technology	YES	C	Radon, VOC, O_3
North Carolina State University	YES	C	$PM_{2.5}$, CO (I&O)
Purdue University (Industrial Hygiene Program)	YES	C	aerosols, gases and vapors
Rice University	YES	C	$PM_{2.5}$
Stanford University	YES	C	PM, aerosols, CO
Tufts University	YES	C	Not provided.
U.S. Air Force Academy	YES	U	CO, CO2, VOC
U.S. Military Academy	YES	U	See Tables 3,4
University of Illinois	YES	C	Particle physical and mechanical properties; air cleaner efficiency
University of Texas, Austin	YES	C	Not provided.
University of Toledo	YES	C	CO2
University of Utah	YES	C	$PM_{2.5}$ (O)
University of Wisconsin-Madison	YES	C	aerosol (I&O)
Virginia Tech	YES	C	$PM_{2.5}$ and PM_{10}, relative humidity, temperature, VOCs, CO_2, CO, air velocity, lighting level

There are 59 ABET accredited undergraduate environmental engineering programs in the United States.[1] These programs were identified via the ABET website and then examined based on information published on their respective program and registrar web sites. Many of the programs surveyed for this work offer their course in a civil, mechanical, aerospace, or environmental health program. In these cases, the air pollution course is an approved elective for the environmental engineering program. Research on the 59 ABET accredited programs suggested that most offer at least one course in the air focus area. Programs that offer hands-on air quality experiences were identified via a brief email survey (63 programs were surveyed). The survey stated that negative responses would be treated as not having a hands-on air quality experience. Sixteen of those surveyed did not respond. However, most of those surveyed responded in either case. Twenty eight percent of those surveyed provide some type of hands-on air quality experience (Table 1). These experiences have been offered in several courses and programs including introductory environmental engineering courses[14] and in environmental sampling and analysis laboratory courses.[17] The most common measurements appear to be particulate matter (PM), CO, CO_2, and aerosols (Table 1). One air pollution project at the University of Utah examined the outdoor concentrations of PM and the students' work resulted in peer-reviewed publication.[22]

An example of a previously published IAP project was described by Eschenbach and Cashman (2004), who reported on students' use of CO_2 meters to determine the ventilation rate of a space of their choosing. The instructor provided a website and associated readings 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 were encouraged to choose rooms on campus where they experienced discomfort that could potentially be linked to air quality.

(3) Project Description

The objective of USMA's IAP Project is for students to design an experimental methodology to explore a potential indoor air pollution problem, collect and analyze data, develop proposed solutions, and submit a written report. The project is issued to groups of three to four students during lesson 4 of the 40 lesson course, in conjunction with the first of two classes concerning IAP. Once issued, students are given approximately 35 days to complete the project. Each group is required to conduct an in-progress review (IPR) with the instructor by lesson 7, approximately one week after the project is issued. The purpose of the IPR is to ensure students have drawn the required equipment, chosen a safe and approved area to conduct the study, and begun to develop a feasible experimental methodology to test their hypothesis.

Hypothesis Development

Before students majoring in our environmental engineering program take our air pollution course, they are exposed to the practical application of the scientific method in their required introductory environmental course. Here, as part of a semester-long term project, students are encouraged to develop a hypothesis and experimental methodology based on a standard 8-step model.[5] This model serves as the basic foundation for the development of experimental methodology in several courses in our program. In general, the experimental methodology asks students to first develop an inference and research question based on physical observation, then develop a null hypothesis, which can be disproven. For the IAP project, students are given the broad guidance to investigate suspected indoor air quality issues at our university. To get them going, students are shown several example projects including testing air quality in the university gymnasium (PM and CO_2), VOC exposure due to cleaning chemicals, and radon gas exposure in buildings; however, students are by no means limited to exploring these specific pollutants. In addition to choosing a pollutant, students choose a location on campus to conduct their research. Students often chose an area that is interesting to them such as dormitory basements, copy rooms, or buildings near the designated smoking areas. Students are encouraged to look for unusual or unique locations, but are also instructed not to begin sampling until the instructor approves the location for safety purposes. At no time are students allowed to enter confined spaces, restricted areas, construction areas, asbestos abatement areas, or mold control areas.

Once the student team has chosen their pollutant and location, they develop a null hypothesis based on the structure in their introductory text.[5] In general, the null hypothesis includes their chosen dependent variable (usually concentration of pollutant), their independent variable (change of location or condition), and statistical populations tested (at least two).

Air Pollution Detection Equipment

USMA maintains a variety of air pollution detection equipment to support this project (see Table 2). While each device is available for commercial purchase, the SKC® Particulate Matter Sampler is currently used by the Department of Defense and is especially applicable to our university's students. During equipment draw, students are quickly briefed by the lab manager on how to operate the equipment; however, one of the ancillary objectives of the project is for students to gain hands-on experience by reading the manual, and experimenting with the equipment prior to gathering samples for their projects.

Development of Experimental Protocol

Once the students have chosen a pollutant, a location, and drawn equipment, they develop an experimental protocol. The protocol includes, at a minimum, the following components: sampling location, sampling times, sampling duration, experimental controls, and their control group. Students are also asked to address any major assumptions they make, and limitations to their experiment they encounter. The students are told that their protocol must be detailed enough that another student group could pick up their final technical report and re-create the experiment. This experience reinforces the engineering thought process and supports attainment of ABET Outcome "b" through the design and execution of experiments and data analysis.

Analysis of Results

Once complete with sampling, students must interpret their data by comparing the concentrations of the pollutants they find with the PEL for occupational exposure to indoor air pollutants established by the National Institute for Occupational Safety and Health (NIOSH). Students are referred to *29 CFR 1910.1000 Table Z-1* for looking up PELs for non-biological indoor air pollutants.[20] Students are encouraged to conduct statistical analyses to determine if there is a significant difference between pollutant concentrations in different areas. If necessary after analyses, students are instructed to conduct additional sampling to further test their hypothesis.

Table 2: Air Pollution Detection Equipment. The following air pollution detection equipment is currently available (as of academic year 2011-2012) to students conducting the Indoor Air Pollution Project at USMA.

Pollutant	Detection Equipment Description	Website
Radon	SafeHome Products Pro3 Radon Detector	http://www.safehomeproducts.com/shp2/product/radon-gas-detector-pro-3-by-safety-siren/radon-monitor-and-alarm/monitor-safety-siren/1449/1449.aspx?b=ie7d&w=1259&h=1258&f=N&tp=99999&frompg=94&topg=0&menupage=975
O_3	EcoSensors A-22 Ozone Detector	http://www.ecosensors.com/a22.html
CO, O_2, CO_2, VOC, Cl_2	Industrial Scientific MX-6 iBrid Mult-gas Detector w/ Photoionization Detector (PID)	http://www.indsci.com/products/portable/mx6.aspx?id=106
HCHO, Cl_2	Draeger One-time Sampling Tubes	http://www.draeger.us/Pages/Mining/sampling-tubes-and-systems.aspx
PM	SKC® Deployable Particulate Sampler	http://www.skcinc.com/instructions/38044.pdf
PM	Airmetrics MiniVol (Model 4.2)	http://www.airmetrics.com/downloads/Manual_V42d.pdf

Note: Despite the usefulness of each of the devices, newer models are available for purchase and we intend to replace these devices in the next several years. Our university is currently in the process of researching and submitting purchase requests for updated equipment.

Technical Report & Final Client Brief

Upon completion of sampling and analyses, each group is required to write a brief 5-page technical article which incorporates their problem statement, experimental protocol, results, significant findings, recommendations, and conclusions. Students are asked to submit the report in a standard science and engineering format and include the following five sections: introduction, materials and methods, results, discussion, and conclusions. Students are referred to several on-line references for guidance on how to write a journal-style scientific article and use statistics.[3,4,16] Students are asked to place tables and figures in appendices, which are not included in the 5-page limit. Each report must also utilize and cite at least five sources, including at least one that is found through the student's research and aids in providing relevant background information. Students are referred to several helpful websites from the American Lung Association, the Environmental Protection Agency, the Center for Disease Control, the Environmental Law Institute, and the National Conference of State Legislators, to gain relevant background information.[2,8,9,11,12,19]

In addition to the written report, students are asked to brief their results to a client, which is usually the instructor, another faculty member, the environmental laboratory manager, or a staff member at our university, such as engineers in the Department of Public Works or the Preventative Medicine Office.

Instructor Assessment

Our IAP project is weighted at 75 points of a 1000 point course, or 7.5% of the student's total grade. Instructors assess their students on the quality of their experimental protocol, the quality of the analysis of their sampled data, the quality of their technical report, and the difficulty of their project. Students are provided formal written feedback on the results of their project. Students are not assessed on their client briefings.

(4) Assessment of the Indoor Air Pollution Project on Student Learning

Previous Project Results

Historical projects include ozone detection near copy machines, particulate matter sampling in the gym or similar locations, radon detection in the basement and lower floors of student dormitories, and CO or VOC detection near designated smoking areas. Radon gas is of particular interest at USMA because Orange County, New York is classified as a Radon Zone 1 by the EPA.[13] Table 3 outlines several student projects conducted during the last two years.

Table 3: Previous Student Projects. The following table lists locations of select projects over the last two academic years.

Pollutant	Project Description	Detection Equipment
O_3	Students measured ozone levels near the copy machine in the environmental engineer's common area.	EcoSensors A-22 Ozone Detector
PM	Students measured the PM concentration in a dusty area of the student dormitory basement.	SKC® Deployable Particulate Sampler
PM – lead (Pb) focus	Students measured the concentration of airborne lead particulates in an indoor pistol and rifle range. Total suspended particulates (TSP) were collected and then later chemically separated from the sampling filter in the laboratory.	Airmetrics MiniVol Version 4.2 PM_{10}, $PM_{2.5}$, and TSP Portable Air Sampler
VOC	Students measured the concentration of VOCs in rooms near the designated smoking areas.	Industrial Scientific MX-6 iBrid Mult-gas Detector w/ Photoionization Detector (PID)

One student study led to further research and the development of a manuscript whose abstract was accepted at the 2010 ASEE North Central Sectional Conference. The students tested for the presence of lead particulates in an indoor firing range and found that users were exposed to a significantly higher concentration of airborne lead than the PEL of 50 µg/m^3 (averaged over an

8-hour period). Their project results were provided to the university's occupational health office and action was initiated to determine the source of the particulate matter. Convinced that this posed a risk to the range's users, two of the students elected to investigate this issue further in fulfillment of a year-long independent study program. They coordinated with our university's occupational health office to assist them in their investigation. The results of the students' experiment led to further environmental testing of the facility and significant changes to the team's practice schedules to minimize exposure times and durations.

Students have encountered several common problems when conducting experiments as part of this project. Related to equipment, students have found that the sensitivity on the MX-6 iBrid Multi-gas Detector for chlorine gas is not accurate unless constantly calibrated. Additionally, students have found that the SKC® Deployable Particulate Sampler will give inaccurate results if the filters are not weighed in the same conditions (temperature, relative humidity) before and after sampling. This issue can be mitigated, but not completely resolved, by desiccating the filters before and after sampling. Additionally, students have sometimes had problems identifying indoor areas with high enough pollutant concentrations to be interesting. Specifically, the designated smoking area, while close to several student dormitory rooms, does not produce enough CO to measure on the MX-6 iBrid Mult-gas Detector likely due to dilution with ambient air. Students have also had issues coming up with areas that have high indoor concentrations of PM.

Air Pollution Engineering Course Assessment Data

The Air Pollution Engineering course at our university has course outcomes, embedded indicators, and subjective ratings used for program assessment and evaluation. One of the six current course outcomes for the air pollution course encompasses indoor air pollution: "explain key topics pertaining to mobile sources of air pollution and indoor air quality." As indicated in Figure 1, this course outcome is assessed by analyzing student performance on homework questions, exam questions, and projects, and by compiling subjective feedback from the students and the instructor. Valid assessment data exists for our university's air pollution course since its inception in academic year 2006-2007. Prior to 2007, the course was a hybrid meteorology and air pollution course. The indoor air pollution project was introduced to the course in academic year 2008-2009; however, we did not introduce additional metrics to independently analyze the effectiveness of the IAP project on student learning. While examining available assessment data, we found that it was very difficult to differentiate between the two diverse topics listed in the course outcome: mobile sources and indoor air quality. Further, in analyzing the exam questions concerning indoor air quality we determined that most of them were general questions on indoor air pollutants, or mass balance calculation problems. These questions assessed student knowledge concerning indoor air pollution, but did not aid in determining the usefulness of the IAP project to student learning.

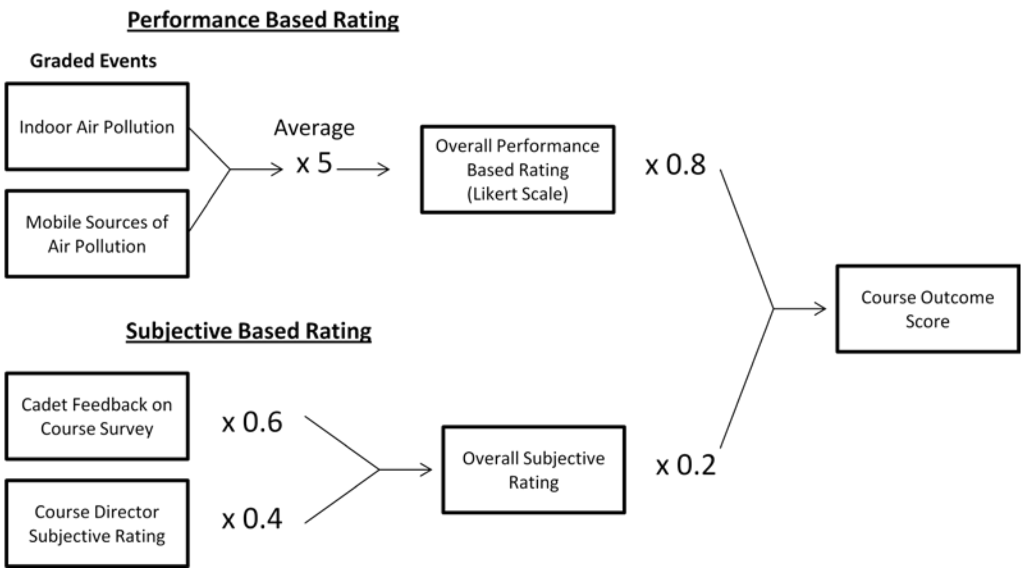

Figure 1: Development of the overall course outcome score concerning indoor air pollution and mobile sources. Due to the nature of the graded events and the questions posed on the course survey, it is difficult to delineate between indoor air pollution and mobile sources. This issue has been corrected for the 2012 academic year.

From this analysis of the course assessment data, we drew four main conclusions: (1) we did not ask the right survey questions to gain meaningful feedback on the indoor air pollution project; (2) questions on the exam only tangentially related to the IAP project; (3) fluctuations in assessment data from year to year had very little to do with the IAP project; and (4) the course outcome needed to be split into two separate outcomes, one for mobile sources and one for indoor air pollution.

Based on these conclusions and in the spirit of ABET Criterion 4, continuous improvement, the following changes are being implemented to our air pollution engineering course during AY2011-2012. First, the course end survey question will be split into two questions. Students will be asked the following: “I can explain key topics concerning mobile sources” and “I can explain major sources of indoor air pollution and propose a plan to sample and control them”. Second, an additional survey question will be added asking: “The Indoor Air Pollution Project was a helpful hands-on experience that aided my learning about indoor air pollution”, which will be answered using a Likert Scale (1-5). Third, the course outcome pertaining to mobile sources and indoor quality will be split into two course outcomes: “describe the major mobile sources of air pollutants and explain technologies used to mitigate their negative effects on the environment” and “explain key topics concerning indoor air pollutants, and develop a hands-on experience concerning indoor air pollution”.

Integration of Student Feedback

At the conclusion of the course in academic years 2010 and 2011, students were asked to give feedback on the project, identify if it was a worthwhile hands-on experience, and comment on its scope. The following is a list of insightful positive comments and constructive criticism concerning the project. The constructive criticism has proven helpful in shaping the project for future terms, and there are several modifications to the IAP project we plan to implement (listed below).

Positive Comments:

- "The greatest educational value was getting to play with the pollutant monitor".
- "I liked getting to investigate actual problems (i.e., student dormitories, Arvin gym, etc.)."
- "I liked the diversity of having different pollutants in different groups."
- "We were able to compare our results to the national average, which allowed us to see where our results stood without comparison to the rest of the class…diversifying the project allows us to explore a number of different issues".
- "I like the diversity of the project so students could choose what type of pollutant they were interested in. I also liked getting to work with/learn new equipment."

Constructive Comments:

(1) In-Progress Reviews (IPRs):

Comment: "I thought the project was too rushed. Although I normally do not like IPRs, I think [a second] one would be a good idea for this."

Modification to Project: Currently students schedule an IPR three lessons, or approximately one-week, after receiving the project. While there is usefulness in having an IPR soon after the project is issued, mainly to ensure students have developed a basic experimental design and have drawn equipment, most students have not yet begun to collect large amounts of data and fail to identify problems that could be discussed in an IPR held later in the project. Having an informal check on progress early, and instituting a full in-progress review later, will likely be more effective.

(2) Presentation of Results:

Comment: "A class presentation on findings/relevancies concerning the indoor air pollutant would provide us with an idea of what other groups discovered".

Comment: "I think that having separate studies was a good idea because it gives everyone a chance to study something specific; however, I think it would be a good idea to show the results to the class or even have a short presentation by each group of their results and methods in addition to the report. This will practice public speaking as well."

Modification to Project: Our air pollution engineering course does not currently have the flexibility to dedicate an entire lesson to student presentations, although there are opportunities for students to present their findings at the beginning of several of the classes immediately following the project completion. A short, no more than 5-minute, briefing will likely help all students understand the methodology and relevant results from other project groups. Student groups with outstanding results will also be encouraged to participate in the university's Project Day, where student groups present posters outlining their significant work throughout the year.

(3) Experimental Design Process:

Comment: "I learn from talking to other groups. I couldn't because everyone had something different to measure it was like we were working on a different project and we couldn't learn from one another."

Comment: "Our experiment design was so basic that I didn't learn much. I think it would help if there were more guidelines for the experimental design."

Comment: "It would have been nice to know of specific locations (aka for PM) that we could obtain good results from. With the PM device we used, we really had no idea where results could be obtained."

Modification to Project: While one of the objectives of the IAP project is for student groups to examine different indoor air pollutants and conduct sampling with different pieces of equipment, we plan to encourage collaboration between groups on the experimental design process. Giving the students a few minutes at the end of class during Lessons 6-8 (within one week after the project is issued) to discuss their project and ask other groups about their experimental design will likely improve the quality of each group's project. Also, we plan on giving students additional ideas about where to sample when the project is issued (Table 4).

(5) Approach for Implementing Hands-On Indoor Air Quality Experiences

This project is most easily introduced to a course that already incorporates a lesson (or several lessons) on indoor air pollution topics. The two course lessons on indoor air pollution and this project compliment the material discussed in class. We suggest a course outcome concerning indoor air pollution similar to the one we are implementing in academic year 2011-2012: "explain major sources of indoor air pollutants, and propose a plan to sample and control them".

Table 4: Possible future projects for students to examine as part of the Indoor Air Pollution Project.

Pollutant	Project Description	Detection Equipment
Hg	Mercury vapors maybe present in water and wastewater treatment facilities or in dental facilities.	Portable Mercury Vapor Analyzer[1] such as: http://www.azic.com/ins_jerome.aspx
Cl_2	Many students complain that the local pool has a strong chlorine odor that can linger. Taking samples during times of heavy swimming may contain elevated chlorine.	Drager One-Time Sampling Tubes, or the Industrial Scientific MX-6 iBrid Multigas Detector
CO or VOCs	Students often have BBQs in the common areas. In rainy conditions, they often move to the sally ports of buildings or underneath overhangs where pollutant concentrations can increase.	Industrial Scientific MX-6 iBrid Multigas Detector
CO	Our university's Mechanical Engineering Department has several indoor multi-fuel engines. While a ventilation system exists, CO concentrations may still increase.	Industrial Scientific MX-6 iBrid Multigas Detector
CO_2	Students conducting gymnastics or indoor obstacle courses often complain of lung irritation and respiratory issues following exercise. Elevated CO_2 concentrations may be to blame	Industrial Scientific MX-6 iBrid Multigas Detector
PM	Our university possesses a local mason shop. Concentrations of PM may build to levels of concern while construction projects are underway.	Airmetrics MiniVol (Model 4.2), or SKC® Deployable Particulate Sampler
PM	Portable personal monitoring devices capable of measuring PM (2.5 or 10), while students are conducting popular activities such as running on the indoor track.	SIDEPAK personal aerosol monitor (AM510)[1]: http://www.tsi.com/SIDEPAK-Personal-Aerosol-Monitor-AM510/
Radon	While students have often conducted radon tests, conducting tests in conjunction with varying external conditions, such as temperature inversions, relative humidity, or precipitation is unique.	SafeHome Products Pro3 Radon Detector
Relative Humidity	While water vapor is not a pollutant, low relative humidity (<30%) in the air can cause discomfort. Higher levels of water vapor (relative humidity >60%) can facilitate the growth of mold.	Hygrometer
VOCs	Many cleaning products release VOCs during use. When students clean their dormitory rooms, the "fumes" can be strong and may contain notable VOC levels.	Industrial Scientific MX-6 iBrid Multigas Detector

[1]USMA is in the process of purchasing a portable Mercury Vapor Analyzer and the SIDEPAK personal aerosol monitor (AM510).

To implement this project at other universities, instructors will need to dedicate approximately 10 minutes of in-class time to introduce and explain the project. A review of the scientific method and statistics may also be necessary. Outside of class, instructors will need to dedicate approximately 15 minutes per IPR per project group. Very likely student groups will need to schedule additional instructor time to work out problems or ask questions. While each student group is different, students will spend approximately one hour learning the equipment, and between 10 and 20 hours developing their experimental protocol and conducting sampling. Analyzing results and writing their technical report will take students approximately 5-7 hours.

In addition to the projects listed in Table 3 that our students have already conducted, Table 4 outlines additional projects that students may examine in the future. While one of the objectives of this project is to allow students to identify their own project and develop their own experimental methodology, several of these opportunities will require additional resources that students will not be able to easily develop or coordinate on their own. Suggested equipment for each project is also listed in Tables 3 and 4.

(6) Conclusion

The indoor air pollution project allows student teams to identify a pollutant of concern (gas or PM), find an interesting location for sampling, and develop an experimental protocol. Once students are supplied with the pollution monitoring devices, they are given approximately 5-weeks to collect data, use statistical analysis to interpret the data, and analyze the results by comparing to PELs established by the NIOSH. Students then present their findings and recommendations in a 5-page technical report, and to a client at our university. This project supports Environmental Engineering Program Criterion 9 as well as ABET's outcome "b", while giving students the opportunity to test a hypothesis, quantify a real-world indoor air pollution problem, and demonstrate significant partnership between professional engineers and students. Since many undergraduate air pollution courses do not offer a hands-on experience (as indicated in Table 1), this project may be of use for those exploring ways to expand student learning.

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