

Engaging social science and humanities students in community-based research on nitrogen oxide pollution

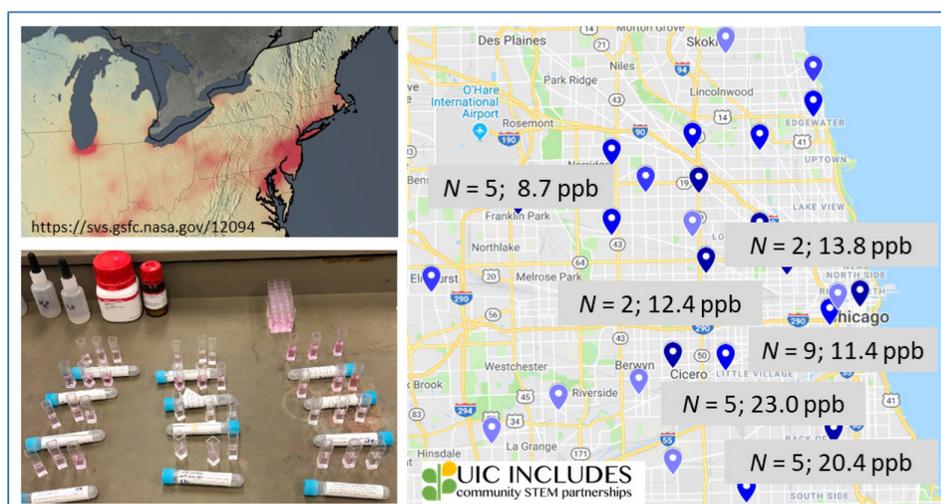
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ABSTRACT

A significant challenge to the community of chemistry education is the creation of materials that
10 can be used in non-science settings, including those of social science and humanities classrooms. As
part of a larger effort to engage new communities in the understanding of how science data can impact
such settings, including in the community, an experiment to detect the level of nitrogen oxides (NO_x)
in the air was implemented in a university and sociology and history classroom. Although the
implementation yielded results that have only semi-quantitative reliability, the use of an authentic
15 scientific method within these settings generated important data for classroom use. The impact on
student attitudes and learning was also determined.

GRAPHICAL ABSTRACT



KEYWORDS

20 General public; General education; Curriculum; History /_____.

INTRODUCTION

There have been many reports of innovative work to link education in chemistry courses to local environmental concerns, including sharing the results to the community. This can occur in many settings. For example, such a focus has been included in chemistry courses, such as in analytical chemistry courses,^{1,2} It is also part of the way that chemistry is included in other science and engineering stings, work to use publicly-available information on brownfield sites to map pollutant locations in a community in environmental engineering.³ Environmental concerns are also at the center of many service learning settings, such as a comprehensive survey of metals in well water,⁴ Finally, because environmental and civic concerns are also a part of education outside of natural science and engineering, inclusion of chemistry in social science and humanities courses is also important, for example in a collaboration of chemistry and political science faculty to support interdisciplinary research teams in the examination of airborne polycyclic aromatic hydrocarbons in different communities.⁵ Such connections will be increasingly important given the recent development of well-grounded perspectives on systems thinking in chemistry, where the environment is often the setting to develop important chemical principals in a complex setting.^{6, SYSTEMS THINKING REFERENCE}

In this paper, we report the introduction of an experiment to measure the time-averaged concentration of nitrogen oxides in an urban environment in two non-science classes (introductory sociology and an urban history class). This supported instruction in the humanities and social sciences and also introduced students to the way that scientific data could provide additional insight into issues of the urban environment.

Re-engaging the disengaged

A well-educated and productive workforce in science, technology, engineering and math (STEM) is crucial to America's global competitiveness in the 21st century. In order to build this workforce, it is imperative that women and people of color be included.⁷ Despite making up a substantial proportion of the U.S. workforce and the college-educated workforce, women and people of color continue to be vastly underrepresented in STEM jobs and among STEM degree holders.^{8,9} One reason for this is the gradual dis-engagement of students during their schooling.^{10,11} In 2010, the President's Council of

Advisors on Science and Technology (PCAST) concluded that the keys to improving science education
50 are “preparation *and inspiration*” (emphasis added).¹² In other words, it is not effective to simply require
students to take more and more difficult STEM courses; STEM must be presented in such a way that
it recaptures students’ interest.

Therefore, this project takes the approach of leveraging the curricular space of a general education
sociology and history courses to provide students—both STEM majors and non-STEM majors—with a
55 positive experience with STEM content embedded in the context of sociology. Understanding
chemistry, especially relative to social issues, is a crucial aspect of participation in a high-tech,
science-informed society, including recent discussions of the role of relevance and social justice in
chemistry education.^{1-6,13,14,15} Further, research shows that interdisciplinary science education with a
socioscientific lens promotes richer understanding and improved outcomes because it situates science
60 in realistic contexts that are meaningful to students.¹⁶ In other words, a socioscientific issue allows
students to practice using science to discuss and debate an interesting problem, including in
particular problems of air pollution.^{17,18}

Measurement of NO_x pollution in the classroom

The measurement of NO_x is something that can be done in real time using electronic means. But
65 NO_x pollution is also something that is important to measure over time, since there can be very large
variations depending on weather and human activity, given how much NO_x pollution is associated
with transportation sources. Therefore, a more meaningful measurement is one that is time-averaged.
This also has the advantage of permitting the use of passive monitoring systems. In the case of NO_x, a
convenient way to do this is with a Palme tube, which consists of a tube of specified length with a
70 single open end. A collection system, usually a wire mesh coated with an appropriate reactant
chemical, is placed at the other end of the tube. The tube is mounted upside down and collects air
passively as it moves past the open end of the tube. Palme tube systems are commercially available¹⁹
but can also be easily constructed for classroom use, following the method reported in this Journal by
Shooter²⁰ and further used in other settings.^{21,22} They are also used in precise environmental work,

75 including with other gases such as sulfur oxides.²³ The specific case of NO_x pollution has also been reported in the context of a study in within the setting of a single university campus.²⁴

COURSE IMPLEMENTATION

Introducing NO_x pollution: general points

In both settings, the course materials included a general structure where students were presented with a lecture about NO_x pollution and introduced to the data collection procedure (See
80 Supplementary Material). This included a discussion of general issues of NO_x pollution over the last forty years, including data from NASA visualizations²⁵ that documents how, overall, satellite monitoring shows a significant reduction of some of the largest distributions of NO_x in North America (Figure 1). This data is encouraging but it also shows the continued presence of significant amounts of
85 NO_x pollution in many areas, including the region where most of the students live. In addition, students are shown information on how NO_x levels can vary significantly within a smaller area. This includes an illustration of data collected in an urban location in Nepal using the same technology.²⁶

The introductory material is also related to larger themes within the classroom. The discussion directs students to consider how the metrics associated with different locations and neighborhoods
90 reflect the social, economic, and demographic aspects of the community. The importance of environmental factors, such as air pollution and exposure to industrial and transportation settings, is discussed as an indication of the way the built environment of a community, including siting of large industry and heavy transportation systems, is also discussed.

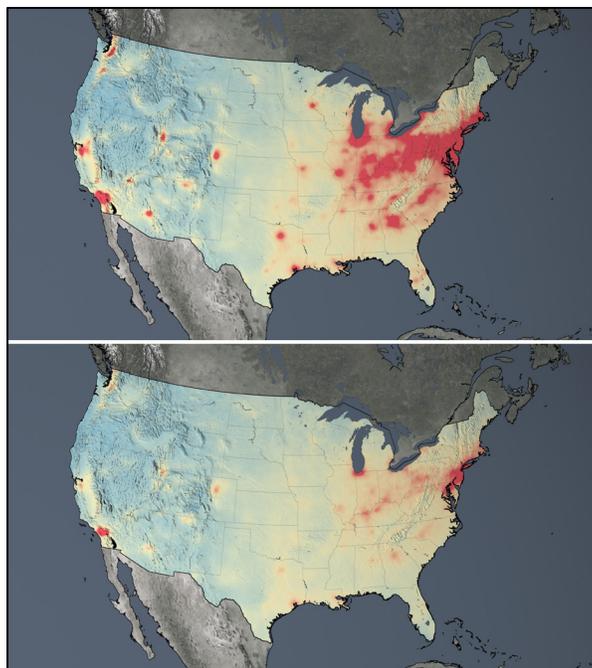


Figure 1. NASA Visualization^{REF} of average NO_x levels over the continental US in 2005 (top) and 2014 (bottom).

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Following the introduction of the question of environmental factors and air pollution, students are introduced to the sampling project itself. The collection kits are shown to the students, including the instructions that come with them (see Supplementary Material for a supply list, including templates
100 for labeling of tubes and instructional cards). Collection kits are prepared for the students using standard procedures.^{SHOOTER} At this or a following lecture, student collection kits are distributed as a set of three capped tubes. Students are asked to return their samples after a one week period. Generally, two collection dates are involved.

Processing of the samples occurs as soon as possible after the collection and at a time when, if
105 they choose, students can come to see the tubes being analyzed. The chemistry of the NO_x sampling has been discussed before. Briefly, the tubes contain a metal mesh that has been treated with 3 drops of a solution of diethanolamine (DEA) and a surfactant. When uncapped and turned upside-down, the reactant solution remains on the metal mesh, a fixed distance from the opening of the tube. During exposure, air passively moves into the tube and NO_x reacts with the DEA to form N-
110 nitrosodiethanolamine (NDELA). It is in this form that the tubes are returned for analysis. Development of the tubes takes the form of addition of water to the tube followed by a solution of

sulfonamide, which undergoes a diazotization reaction with any nitroso groups. This is then treated with a solution of naphthylamine hydrochloride to form a brightly colored diazo dye, which is measured spectrophotometrically. The concentration of the diazo dye is determined by relation to a calibration curve prepared using sodium nitrite standards. This yields a concentration and a mole amount of diazo dye for further calculations.

Figure 2 shows a sample layout of the materials, with Figure 2b showing a set of cuvettes containing different samples and illustrating the significant variation in the intensity of the diazo dye product. The samples are analyzed in triplicate and then loaded into a spreadsheet where data is registered by sample number and by location.

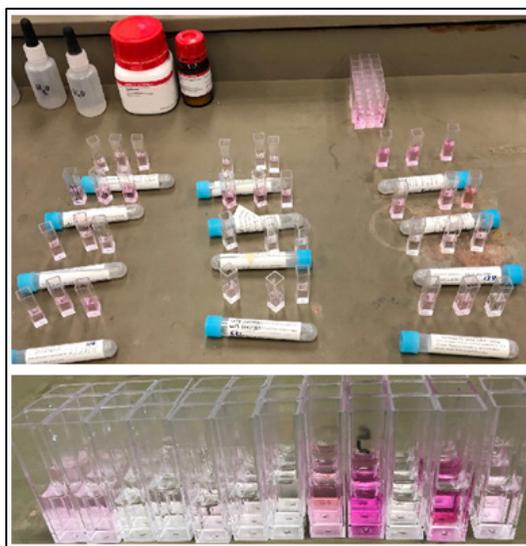
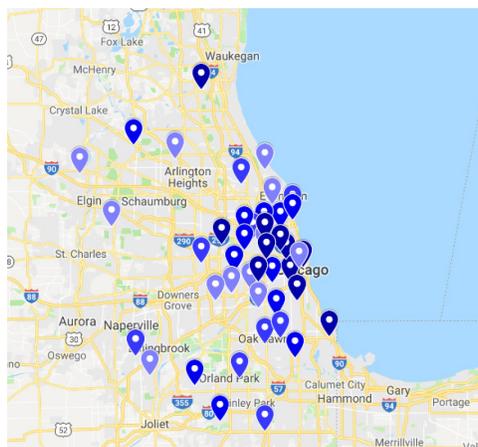


Figure 2. Student samples prepared for spectrophotometric analysis.

The spectrophotometric analysis gives an amount, in moles, of NO_x that was present in the exposed tube. This can then be converted into a time-averaged amount of NO_x through standard calculations that take account of the geometry of the tube and the duration of exposure.^{SHOOTER} Results are reported in the form of NO_x levels in parts per billion.

Once all samples are processed the results are returned to the class for their further use. The results are reported by sample number, which allows individual students or groups of students to know the specific values obtained for their samples. In addition, results are prepared in the form of average amounts by location. We have found that this is best done in two forms: by region and also by zip code. Figure 3 shows a typical presentation to the class. Note that the data as presented shows

data for each geographic location in the form of a colored marker. If more than one sample was available from a particular zip code, that data is shown numerically as well.



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Figure 3. Geographic presentation of results. Four data ranges are present: 0-7 ppb; 7-10 ppb; 10-13 ppb; 13-25 ppb.

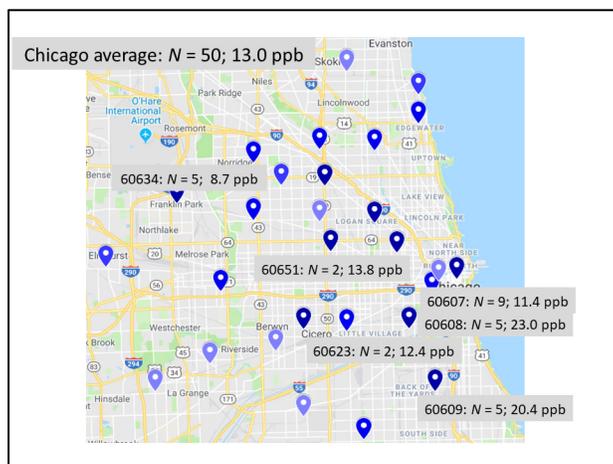


Figure 4. Geographic results including numeric values for zip codes with 2 or more samples.

The results are presented to the class in the form of a follow up lecture. The data are discussed at two levels. First, the overall averages for samples in different regions (within the city and the suburbs—supported by the illustration in Figure 3). This demonstrates a higher level of NO_x in the urban locations, even at this level of precision. Further, data within the city itself (Figure 4) are presented to students with a chance to discuss, as a whole class, the different patterns. Students are able to note that there are generally higher levels (darker markers) in regions that are adjacent to major highways and the location of major train yards.

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IMPLEMENTATION IN SOCIOLOGY AND HISTORY

[Discussion of how Ray Muhammad integrated the materials into Sociology]

[Discussion of how Elisabeth Todd-Breland integrated the materials into History]

STUDENT IMPACT

150 The implementation of this activity was designed to have particular impacts in how students in non-STEM classes understood the role of STEM and scientific data in understanding historical and contemporary aspects of human environments. To examine this, project researchers and evaluators collected data through surveys and focus groups.

The assessment of this project was carried out with a meaningful number of participants within 155 the first year sociology course. Students were primarily in their first or second year of college (79%). The course included more female students (71%) than male students. Racial diversity in the course reflects that of the urban university: 39% of students self-identified as Latino/a, 30% as Asian, 19% as White, and 10% as Black. Approximately two-thirds of students reported a major. Of those, the largest group ($N = 89$) were in health professions or pre-professions (e.g., kinesiology, pre-nursing), 73 160 students reported STEM majors (e.g., mathematics, biochemistry), and 53 students reported humanities, social sciences, or undecided majors. At the beginning of the semester and end of semester, students completed paper surveys that included demographics and scales regarding attitudes toward STEM courses and careers. The present study looks at two scales: STEM interest (e.g., I enjoy taking STEM courses) and STEM self-efficacy (e.g., How confident are you that you can 165 learn STEM material well?). **WE WILL NEED TO DEFINE ORIGIN OF SCALES**

Of the original 319 participating students, 207 either did not complete both pre and post assessments or did not indicate a major. Since major was an important variable of interest, and non-responses appeared to be distributed randomly across majors, we excluded students who did not indicate a major. (Students who wrote “undecided” or similar are included in the analysis.) In order to 170 understand how the socio-scientific learning impacted male and female students, non-White and White students, and students in different majors, we divided the class into groups by race, gender, and three categories of declared majors: STEM majors, health majors, and other majors.

STEM Self-efficacy was found to increase significantly for two groups of students: female STEM majors (pre: $M = 4.02$, $SD = 0.78$ to post: $M = 4.24$, $SD = 0.77$; $t(25) = 2.12$, $p = .04$) and for non-White health majors (pre: $M = 3.39$, $SD = 0.96$ to post: $M = 3.63$, $SD = 0.99$), $t(32) = 2.23$, $p = .03$). *STEM Interest* increased significantly for female health majors, (pre: $M = 3.24$, $SD = 0.83$ to post: $M = 3.50$, $SD = 0.95$; $t(33) = 2.72$, $p = .03$), for non-White health majors (pre: $M = 3.32$, $SD = 0.95$ to post: $M = 3.56$, $SD = 0.99$; $t(32) = 2.14$, $p = .04$) and for non-White STEM majors (pre: $M = 4.15$, $SD = 0.77$ to post: $M = 4.36$, $SD = 0.70$; $t(25) = 2.19$, $p = .04$).

Based on these results, the project appears to have partially succeeded: female STEM majors showed increased levels of STEM self-efficacy at the end of the course, and non-White STEM majors showed increased levels of STEM interest at the end of the course. For these groups of students, who are statistically at greater risk of not finishing a STEM degree, an improvement in STEM attitudes is a positive and promising result. The project also had positive impacts on students in health majors. These students are likely taking numerous STEM courses that focus on the healthcare applications of science and technology. Non-White students majoring in health fields saw increases in STEM interest and self-efficacy, as did female health majors.

Unfortunately, and somewhat surprisingly, the project did not have the intended benefit for students who are not majoring in STEM or health fields; i.e., those who are majoring in humanities, social sciences, or other fields. As we proceed with refining and developing this curricular unit, it seems crucial that non-STEM students be well supported with adequate time and in-class preparation, in order to have a successful experience that will help them re-engage with STEM. Future iterations should include more in-depth research around students' experiences with the curriculum in order to understand how students of different backgrounds and majors engage with the socioscientific units.

The project evaluator conducted 10 mini focus groups before and after sociology course. Group size ranged from 1-5 people. We didn't observe noticeable differences between STEM majors and non-STEM majors. While students didn't see an "impact" of the inclusion of STEM in SOC, some noted new insights as follows the value of combining the way to think sociologically and scientifically as a combination...how people behave influences the environment around them—having a sociological perspective combined with science perspective helps to deepen understanding. Students also noted

the impact of how issues such as the quality of air could affect disparities. Although there was more interest in STEM in some cases, no students indicated an interest in switching. The students also noted some frustration with the project management, including the size and organization of the data collection groups and the time gap between obtaining data and the results, which may have prevented
205 a rich discussion in class about integrating findings with sociology.

The subsequent implementation in a history class was informed by these results. However, for this class there was also a shift from paper-based to on-line assessment of student consent also collection of survey data. A much lower response rate (less than 10% of the class) meant that systematic data could not be collected. However, the class did provide a much higher level of participation in the data
210 collection itself, indicating some success at improving the management of the activity.

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