Development and Implementation of a Water Quality Testing Module Across the Curriculum: Science, Liberal Arts, and Art/Design Majors

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THE NEW SCHOOL UNIVERSITY SCIENCE LABS

Abstract
In 2015 lab staff developed and implemented a Water Quality lab module for undergraduates in introductory and intermediate courses serving design and liberal arts students. Students acquire technical skills, review the scientific method, and gain content knowledge regarding genetic diversity and metabolism within customized course contexts. In a variety of courses, the 69-84% of students find the module is useful, and a smaller percentage would like to see more modules introduced in other courses across the curriculum. Instructors have similarly had positive experiences and continue to include the module in their course.

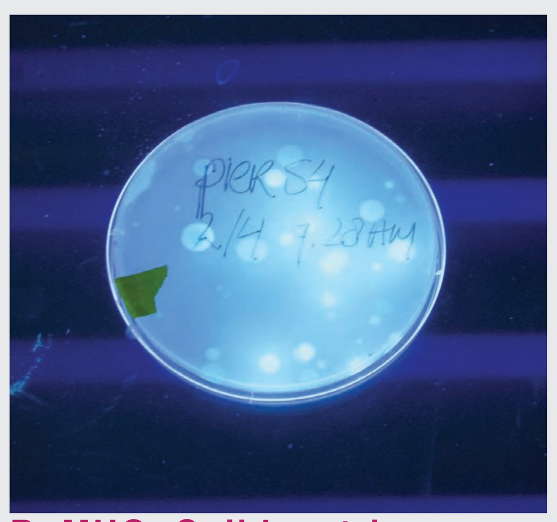
Questions
1. Can we design a biology-based water quality lab module that is economical, scalable, and customizable in terms of context, for students studying design, liberal arts, and STEM?

2. Can the lab unit be done in two, consecutive 75-minute sessions across two weeks?

3. How can we assess student experience, skills gained, and knowledge retained?

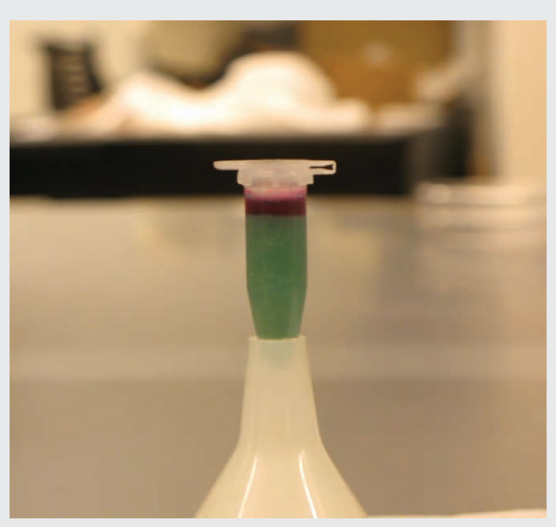
Methods
The Water Quality module is designed to teach the epistemology of science using bacterial coliform detection systems and highlights civic relevance by explaining how government agencies and citizen scientists implement this protocol to monitor human influences on public water systems. The module uses a simple chromogenic assay (~$1/student) to aid students in the understanding of a central biological concept: both genetics and environment determine metabolic phenotype. Additionally, lab staff share the basics of sterile technique, manipulation of variables, and the value of reference standards. Through the lens of sustainability and social justice, the module explores water as a limited resource, disease communicability, and the role of infrastructure design in mitigating downstream effects of climate change. We have adapted this module for different courses by incorporating additional selective assays, confirmatory biochemical reactions, and broadened the context by exploring point-of-use filtration techniques.


A. Oxoid: Solid matrix


B. MUG: Solid matrix


C. Hyserve: Solid matrix

D. Edvotek: Liquid media


E. Edvotek: Indole reaction

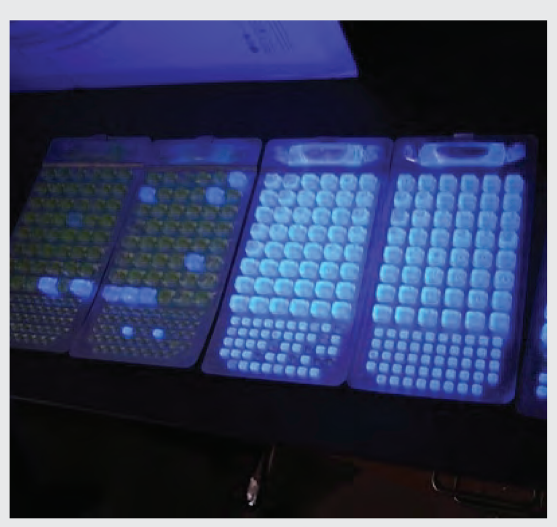
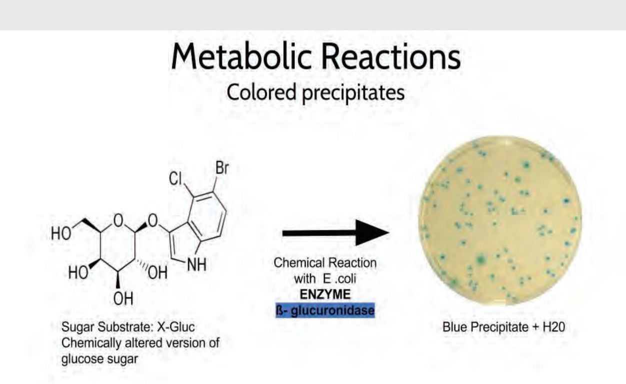

F. IDEXX: Liquid media

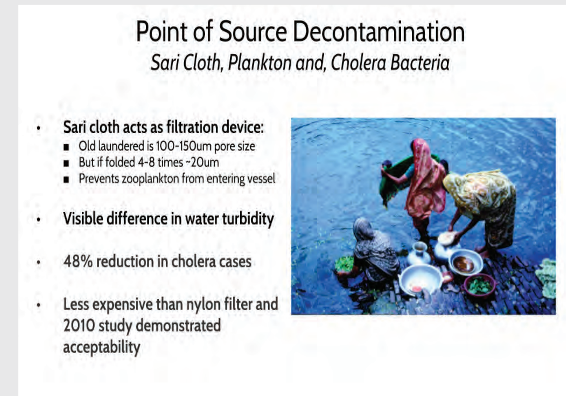
FIGURE 1. Visualizing Metabolism: Chromogenic and Fluorogenic Liquid/Solid Media
We explored various coliform detection assays, using solid or liquid media in an effort to identify the best options for scalability and visualization of sugar metabolism for our student populations. For introductory courses where students have no scientific experience, we use one colorimetric test. For intermediate lab courses targeting STEM majors, we use two to three assays. **A.** Oxoid solid media uses Rose-Gal and X-Gluc as sugar analogs resulting in bacterial production of colored by-products. **B.** MUG solid media releases a fluorogenic compound after being hydrolyzed by human coliforms. **C.** Hyserve Compact Dry EC solid media uses Magenta-Gal and X-Gluc which result in purple and blue precipitates upon being metabolized by bacteria. **D.** Edvotek combines both chromogenic and fluorogenic substrates to produce blue and blue/fluorescent compounds. **E.** Edvotek confirmatory test uses Indole as a chromogenic test to rapidly confirm the presence of *E. coli* within a sample. **F.** IDEXX Quanti-Tray uses fluorogenic media and individual 'cells' to focus on quantitative interpretation of results.



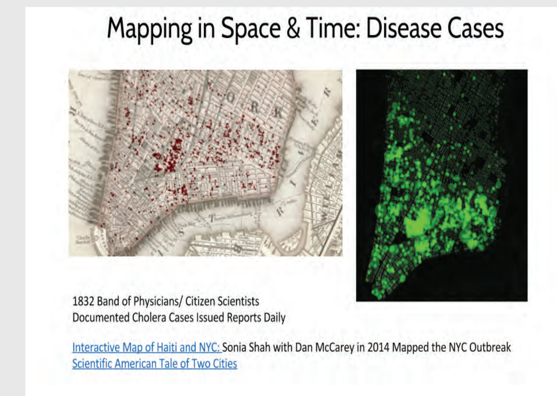
Metabolic/Genetic Diversity
Conceptually, students learn that both genetics and environment determine phenotypic outcomes. They learn that general coliform and human coliform share some genes and phenotypes (the ability to metabolize lactose) but also have genetic differences that allow human coliforms to interact with their natural environments, displaying metabolic preferences for different sugars (preference for glucose over lactose).

TABLE 1: Comparing Costs, Time, and Protocols
We analyzed the cost, preparation time, and protocol difficulty for students. Of note, protocol difficulty relates to student engagement. Protocols with little difficulty offer fewer chances for mistakes and contamination but, also have less opportunity to learn technical skills. Costs range from about $1 to $2 per student per sample. IDEXX Quanti-Tray tests required the purchase or renting of a 'sealer' from the IDEXX company. Prep time includes sample gathering, media making, and class set-up. Hyserve becomes more affordable as more students are served, as bulk purchases reduce costs.

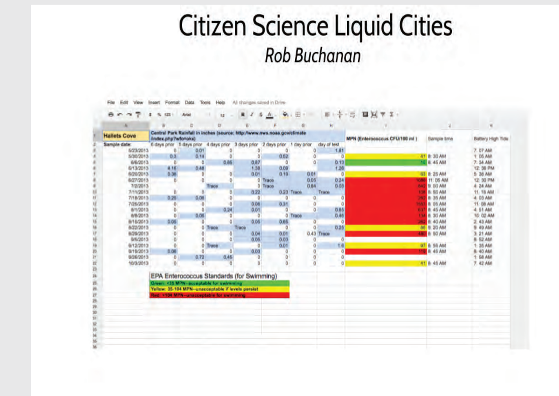
TEST:	COST:	PREP TIME:	DIFFICULTY:
HYSERVE	+ +	+	+
EDVOTEK	+	+ +	+ + +
OXOID	+ +	+ +	+ +
MUG	+ +	+ +	+ +
IDEXX	+ + +	+	+



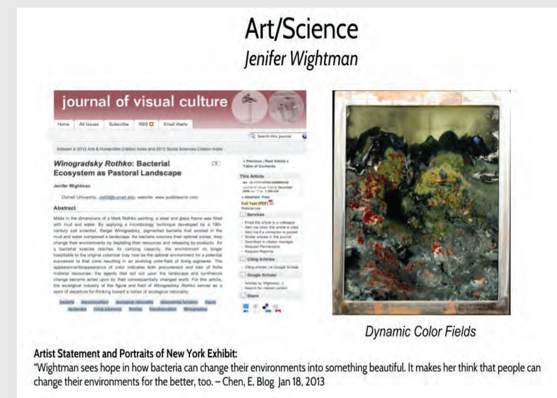
A. Filtration/Sari Cloth



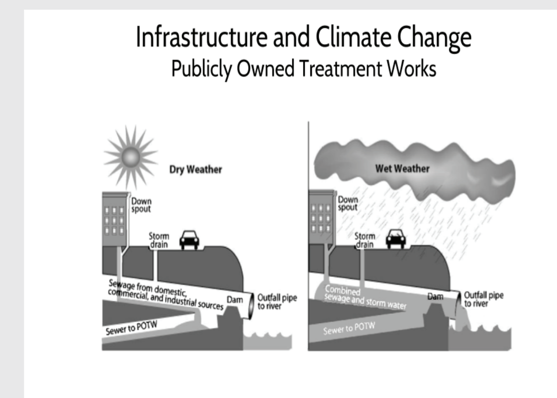
B. Epidemiology/Disease



C. Policy/Citizen Science



D. Art-Science/Ecosystems



E. Design Solutions/Climate

F. Social Justice/Labor

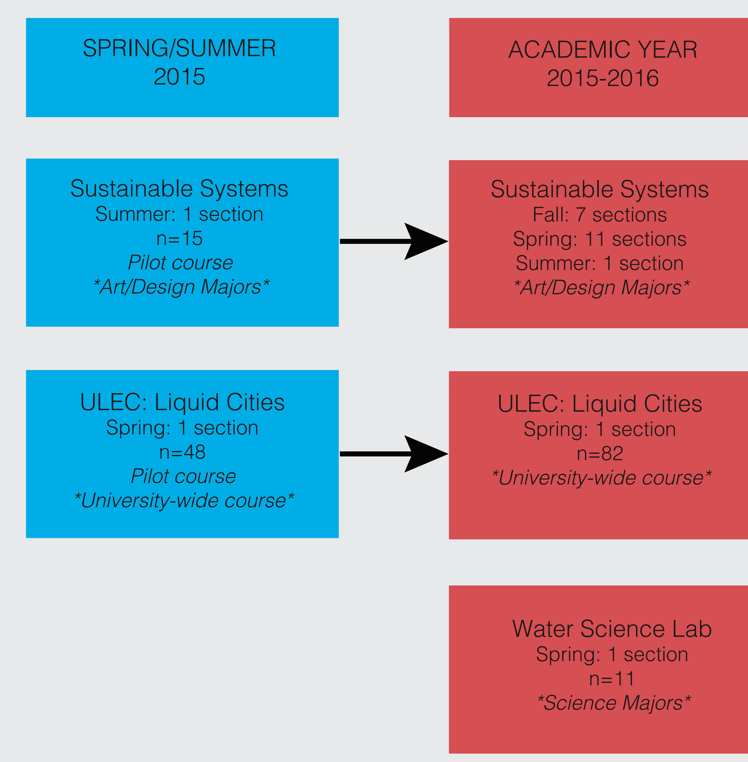
FIGURE 2. Customizing Context
***Biology/Epidemiology:* (Fig. 2A,B)** We explore the spread of infectious disease while discussing cholera outbreaks, water filtration, and the development of investigative mapping tools within the field of epidemiology.

***Public Policy/Citizen Science/Data Collection:* (Fig. 2C)** We show how data collection can influence public policy and how citizen science groups are shaping public narratives about human impacts on ecological systems.

***Art and Design:* (Fig. 2D,E)** We use relevant art-science projects, current design interventions, and an in-class activity where students propose sustainable design solutions for problematic infrastructure. We discuss climate change and it's relevance to designers and urban planners.

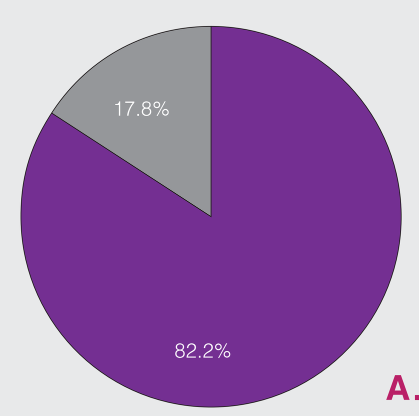
***Social Justice:* (Fig. 2F)** We discuss union contracts and occupational health hazards to emphasize the importance of municipal water systems and investment in access to clean water.This provides a framework to include human rights and worker's rights.

FIGURE 3. Curriculum Expansion
In spring 2015, we piloted the Water Quality module in a university-wide lecture course (ULEC), Liquid Cities and we also piloted the module during summer sessions in a single section of a core course (Sustainable Systems/SS) offered to all freshman studying design at Parsons. Bases on the results collected in these two pilots we incorporated the module into ~9 sections of SS/semester over the past two years. We have also delivered this module to upper-level Interdisciplinary Science and Environmental Science majors while adjusting the complexity and intensity of the module. Our goal is to continue to find ways and opportunities to incorporate science and hands-on lab experience into the curriculum where it might otherwise be absent.

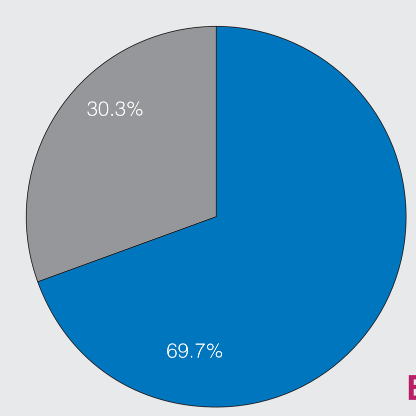


Collaboration with Faculty
"Through this, I aimed to trace patterns of pollution and other environmental factors including water contamination - to discriminatory housing, land-use, and land-access patterns globally and locally. Additionally, I aimed to have the students participate in the experiment, see the results, and from this have "hard data" to put a face on the severity of this issue when met with patterns of social and spatial injustice.***Nadia Elokdah, Parsons faculty***

This is valuable far beyond the actual experimental design [and]specific 'water quality' inquiry.For example, students learn the basics of sterile technique and lab etiquette... 'non-art' confidence, physical lab vocabulary, and comfort with inquiry of 'invisible things' like microbes in your water. By doing, these self-defined 'artists' are experiencing they are also implicitly scientists. ***Jenifer Wightman, Parsons faculty***



A.



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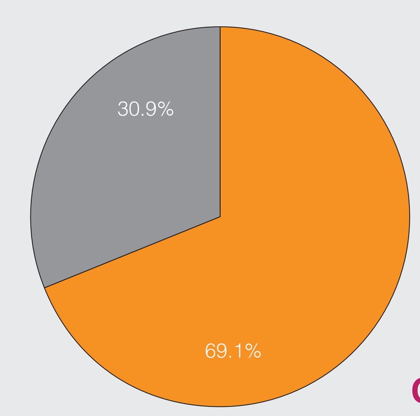


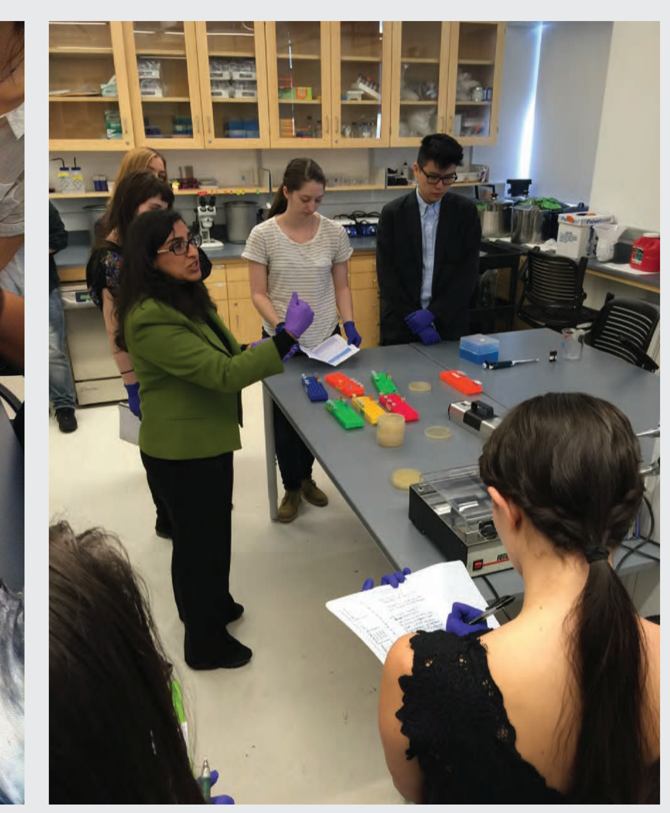
C.

FIGURE 4. Development of Methods to Collect Student Response
We have used several approaches to determine whether non-science majors feel they would like to have more science exposure in their coursework:

(Fig. 4A) We included the following in an online course evaluation: Thinking about the science lab experience in this course, please indicate if the hands-on lab time was: too much, the right amount, too little, unnecessary, or n/a. Over the 2016-2017 academic year (n=185), 82.2% of Parsons students indicated the lab exposure was either the 'right amount' or they would have liked more lab experience within that same course.

(Fig. 4B) In the same course evaluation, we included: Please indicate how much lab experience you would like to have in other relevant Parsons courses. For the 2016-2017 academic year (n=185), 69.7% of students indicated they would like to have the same amount or more lab exposure in other courses.

(Fig. 4C) Initially, we used in-class, handwritten assessments. We are still working out best methods to collect data on the student experience. However, in the Fall of 2015 (n=55), 69.1% of students indicated they would like the same amount or more lab exposure in future courses.



Sample Student Quote From Course Evaluation
"I learned how to integrate science into design, and how seamlessly they work hand in hand. I also saw through experience that science does not have to be reserved for those heavily dedicated to the field; it is a subject that is both approachable and necessary for everyone to be able to understand."

Conclusions
The Water Quality module is a cost-effective and scalable approach to bringing lab learning to a wide range of undergraduates. Because The New School does not require math or science for matriculation, for some students this exposure provides them with some familiarity and context of scientific experimentation through a relatively simple but important assay. We have provided a framework for contextualization and implemented the module in courses ranging from n=16 to n=100. Courses include an introductory STEM course (epidemiology), a required first-year core course for design students, an intermediate STEM lab course, and a university-wide lecture (Liquid Cities). Based on preliminary data, the module resulted in a positive learning experience for over half of the design students (n=185), 99% of the university lecture students (n=23), and 100% of the epidemiology students (n=16). Additionally, student responses to questions regarding the role of sterile water and lab grown bacteria indicate that some obtain a cursory understanding of the role of reference standards and negative controls.We plan to refine our assessment instruments and collect data on student learning outcomes specific to this module as well scientific epistemology.

Acknowledgments
Bhawani Venkataraman, Robert Buchanan, Alison Schuettinger, Clarence Elie Rivera, Jenifer Wightman, Nadia Elokdah, Michele Laporte, Adrienne Reynolds, Timo Rissanen, Laura Sansone, Marina Delgado, Frank Martinez, Ariel Farrell, Michaela Manzieri, Jane Mitchell, Ivan Rameriz, Kimberly Tate, David Bergman, Donna Maione, Toni Castro, Rebecca Silver, and Dylan Gauthier.

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