PROJECT REPORT

Life in and Around the Chicago River: Achieving Civic Engagement through Project Based Learning

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Abstract

By the year 2016, the Environmental Protection Agency (EPA) aims to make the Chicago River an area designated for primary contact recreational use, where people can swim in the water without being harmed by waterborne pathogens from raw sewage contamination (EPA 2011). In recent years, recreational use of the Chicago River has been increasing. Currently only three of the Chicagoland area's water reclamation plants disinfect their wastewater (Oh 2012). The focus of this research project was to determine the coliform count and identify the bacteria within the Chicago River. This mission was performed by undergraduate students enrolled in a microbiology research course centered on project-based learning (PBL) at Harold Washington College (HWC). This endeavor allowed students to learn basic laboratory skills currently used in the field of microbiology and apply them in a real-world scenario. In addition, the students learned the value of collaborative learning and research, along with its outcomes. The results of this project can serve to engage the public by educating them about the pollution in the Chicago River, an invaluable resource shared by many locals and tourists in the Chicagoland area.

Introduction

If there is magic on this planet, it is contained in water, and the Chicago River is a testament to that (Eiseley 1959). The Chicago River has played a critical role in the history of Chicago and continues to be utilized to this day. As has been often repeated, the city of Chicago owes its existence to the Chicago River, and the river owes its present form to Chicago. Geographically speaking, had it not been for the river's location between Lake Michigan and the Des Plaines River, Chicago would never have become one of the nation's central transshipment points (Hill 2000). Since that time, the Chicago River has come a long way from being a cesspool to today's recreational hot spot.

In the nineteenth century, city sewers drained into the Chicago River, which emptied into Lake Michigan. This posed a health hazard, as the lake supplied the city's drinking water (Brown, 2002). In 1900, the completion of the Sanitary and Ship Canal reversed the flow of the Chicago River to direct sewage away from the lake, and after 1922, water treatment plants were established. Today, the Chicago River is used for recreational purposes where tourists hop aboard tour boats and water taxis. Some residents kayak on the river despite the fact that it sometimes receives bad press due to its polluted ecosystem. The EPA's goal is to designate the Chicago River as an area safe for primary contact recreation use by 2016, meaning that people will be able to enjoy direct contact between their skin and the water without being harmed by waterborne pathogens from raw sewage contamination (EPA 2011). Moreover, Mayor Rahm Emanuel has launched a development project for the Chicago Riverwalk, attracting residents and tourists alike to enjoy activities along the main branch of the river. However, only three out of seven of the Chicagoland area's water reclamation plants currently sanitize their wastewater before pumping the effluent back out into the river (Oh 2012).

The main goals of this research are to:

1. Show the impact of learning that resulted in civic engagement through project-based learning conducted by undergraduates.

2. Demonstrate the ability of two-year college students, when given the opportunity, to engage and conduct critical research such as the investigation of water quality in the Chicago River, and to supply results and outcomes that could make a difference in the quality of life around the river. Such work is at the core of civic engagement.

3. Investigate the water contamination level in the Chicago River by determining the coliform count and bacterial identification. Coliforms are gram-negative bacteria that originate from the large intestines of warm-blooded animals and are therefore used as an indicator of fecal contamination. If coliforms are found in water, other pathogenic bacteria may be present as well. Pathogens commonly found in wastewater effluents include *Escherichia coli*, *Streptococcus*, *Salmonella*, *Shigella*, *mycobacterium*, *Pseudomonas aeruginosa*, *Giardia lamblia*, and *enteroviruses* (North Carolina Department of Health and Human Services 2011).

This investigation was carried out as part of an interdisciplinary microbiology research course that was designed and taught based on Project-Based Learning (PBL) methods. There is no doubt that the ways we teach and engage students in learning affect students' attitudes toward, and performance in, college-level courses. Educating our students within the classroom about science, technology, engineering, and mathematics (STEM) is not enough. Science is not simply what students learn from textbooks or from a traditional passive learning environment. Students need to be taught how science is practiced, because it is through science and math that our world is rapidly evolving, with new discoveries being made through inquiry and experimental research. Teaching students scientific concepts through engagement in scientific inquiry and empirical research enables them to understand how math and science fields play a critical role in our society and in our everyday life. When students experience this through hands-on learning and empirical research, their creativity and intellectual boundaries are expanded, and their problem- solving skills and cognitive abilities improve and advance. It has been shown that students learn more effectively when they are engaged in hands-on learning experiences directed by students themselves (Brickman et al. 2009).

PBL has the potential to be a highly effective teaching method that fully engages students and leads them to success in mastering the course material. It greatly increases student motivation to learn course material, due to the impact of connections made outside of the conventional classroom setting. It is an alternative approach to education that encourages students to seek solutions to challenging and relevant problems and to bridge the gap between school and the real world (Doles 2012). In addition, the PBL method allows the student to retain the course material for a longer period of time than the methods employed in a traditional course. A study performed by Cherif, Movahedzadeh, Adams, and Dunning on why students fail in college-level courses, presented at the Higher Learning Commission (HLC) conference in 2013, revealed that lack of motivation is among the most common factors that contribute to student academic failure (Cherif et al. 2013). Lack of motivation was also recognized by many faculty members as one of the root causes of student failure (Cherif et al. 2014). When students realize the significance of the subject being taught and how it relates to their lives, they are more likely to become motivated and engaged. A PBL environment may also change the attitude a student has towards a course or career path (Chang et al. 2011). This is significant, especially because it has been documented that 50 percent of students seeking an associate degree require remediation, while 20.7 percent of those seeking a bachelor degree require remediation (The State of College & Career Readiness 2013).

PBL is an innovative and promising teaching method that imparts to students the skills needed to compete and succeed in STEM field jobs. PBL teaches students important skills such as critical thinking, collaboration with others, taking responsibility for their learning, and time management, among others. PBL is a key learning methodology that prepares students with the skills that are required by employers in STEM fields. Today employers expect professionals not only to hold strong technical skills, but also to be able to work well in teams, manage their time efficiently, multitask, and effectively communicate information gathered from a variety of sources (AACC 2010). Students in PBL classrooms learn and continuously exercise these important skills. Positive outcomes have been revealed at universities such as Southern Connecticut State University (SCSU), where students in a general chemistry course completed a project of their choice related to chemistry. The majority of the students had a positive sense of having gained an "understanding of the multidisciplinary nature of societal issues" and how chemistry aids in addressing real-world issues (Webb 2013). Similarly, this research project revealed the important role biotechnology plays in our society as a means of addressing issues such as water contamination.

We are rapidly moving forward with advancing technology, but there is a lack of skilled and qualified personnel adequately equipped with knowledge in using such advancements. If we are quickly developing innovative technology through research and development, and the demand for skilled workers, such as lab technicians, is ever increasing, then why are students not being taught the skills employers are looking for or the skills necessary to succeed in STEM field jobs? As we will show, PBL methodology grants students opportunities to learn to be self-directed in their education and to acquire the skills they need.

The research project discussed in this paper incorporated the use of current microbiology techniques for students to investigate water contamination in the Chicago River. Integrating PBL in science courses can inspire students to pursue science-related careers. Moreover, these types of projects can positively impact students and encourage them to engage pressing issues in their community and educate the public about such issues. The results of this research call for civic engagement, because the Chicago River is a dynamic resource that is shared and utilized by countless residents of Chicago for various purposes. Given support and minimal resources, students at the community college level are able to actively participate and flourish in research that both recognizes and addresses matters concerning their society and their environment.

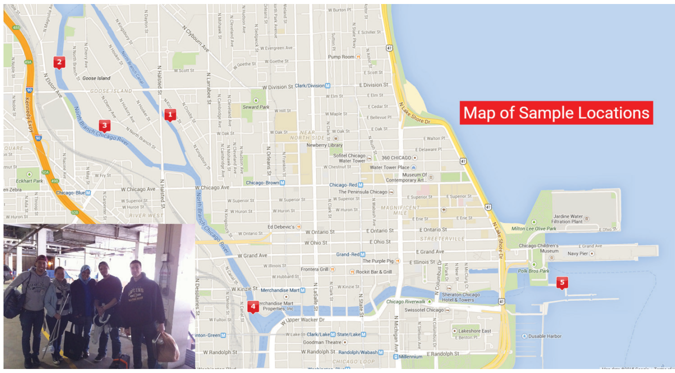
Materials and Methods

Undergraduates were tasked with planning and implementation in all of the aspects of this course, including but not limited to the design of and participation in sampling, testing, research, and synthesis of information.

Sample collection

Water samples were obtained on two separate occasions under two diverse weather conditions. Samples were taken from one location, under the Wabash Avenue Bridge, during inclement weather when torrential rains precipitated the opening of the locks leading from the Chicago River into Lake Michigan due to flooding (April 18, 2013). Water samples reflecting dry weather and normal river conditions were collected at five sites along the Chicago River (fig. 1) on a separate day approximately two weeks later (May 3, 2013). In selecting the sites for the testing samples, covering a large area along the river across multiple neighborhoods where residents use the river in various ways was desired. Samples were collected using a one-liter graduated pitcher attached to an eight-foot pole. Two water samples per location were collected from approximately six feet below the surface, poured into collection bottles, and taken to the microbiology lab at Harold Washington College (HWC) for analysis.

FIGURE 1. Map of five locations from which water samples were collected



Bacterial Count

To determine coliform counts, serial dilutions of 1:1, 1:10, 1:100, and 1:1000 were made from the samples taken during dry normal conditions as they more accurately reflect the ongoing contamination of the Chicago River. MacConkey's agar plates were inoculated with 100 µL of each dilution. After incubation at 37° C for 24–48 hours, colony-forming units (CFUs) were determined. Final results represent the average of both samples per location as shown in table 1. While the applied approach may differ from the methods utilized by the Metropolitan Water Reclamation District (MWRD) plants, the way we submitted the report of the colony count is the standard method and comparable to theirs.

Culture Identification

Bacterial differentiation began by inoculating 100 µL of each non-diluted sample onto the following media: MacConkey's agar, blood agar, Eosin-methylene blue agar (EMB), and triple sugar agar (TSA). After overnight incubation at 37° C, gram negative colonies were selected and isolated to inoculate into nutrient broth for further testing.

Biochemical Identification of Isolates

In addition to the IMViC tests, the following biochemical tests were performed for bacterial differentiation: glucose broth (with and without oil), lactose broth, nitrate broth, gelatin agar, starch agar, spirit blue agar, phenylalanine deaminase, methyl red/ Voges Proskauer, esculin hydrolysis, urea hydrolysis, oxidase and catalase production. To confirm the identification, Enterotube Multitest System (BD BBL, USA) was used for each sample and incubated at 37° C for 24–48 hours. Results from all tests were determined (table 1) using the Bergey's Manual of Determinative Bacteriology (1994).

Results

Testing the water in the Chicago River led to the isolation of coliforms like *Pseudomonas aeruginosa* (fig. 2, originating from flood water sample), *Escherichia coli* and opportunistic pathogens like *Enterobacter agglomerans* and *Serratia odorifera* (table 1). Since the presence of coliform bacteria was suspected, a series of biochemical tests was designed to investigate the fermentation and oxidation properties of the isolates. The bacteria were first tested for their ability to ferment lactose, since bacteria commonly found in water, such as E.coli, are lactose fermenters. The inoculated MacConkey agar plates displayed smooth, round, pink colonies which denoted lactose fermentation. All the results were confirmed using Enterotube Multitest System. Based on the series of biochemical tests performed, the resulting physiological characteristics were matched to the isolated enterobacteria (table 1).

Bacterial counts obtained by the undergraduates conducting this project are comparable to bacterial counts obtained by the MWRD after weekly testing of effluent wastewater released from both its O'Brien Water Reclamation Plant and Calumet Water Reclamation Plant between 2005 and 2010 (MWRD 2011). The bacterial count obtained from Site 3 had a higher count than the highest recorded at the Calumet Water Reclamation Plant (120,000 CFUs /100 mL), yet lower than the highest count recorded at the O'Brien Water Reclamation Plant (200,000 CFUs /100 mL) (MWRD 2011). Site 5, where the lowest number of CFUs were recorded by undergraduates, had a count above the minimum CFUs reported at

FIGURE 2. *Pseudomonas aeruginosa* Photo selected as "Picture of the Day" for the American Society for Microbiology website (www.asm.org) September 30, 2014

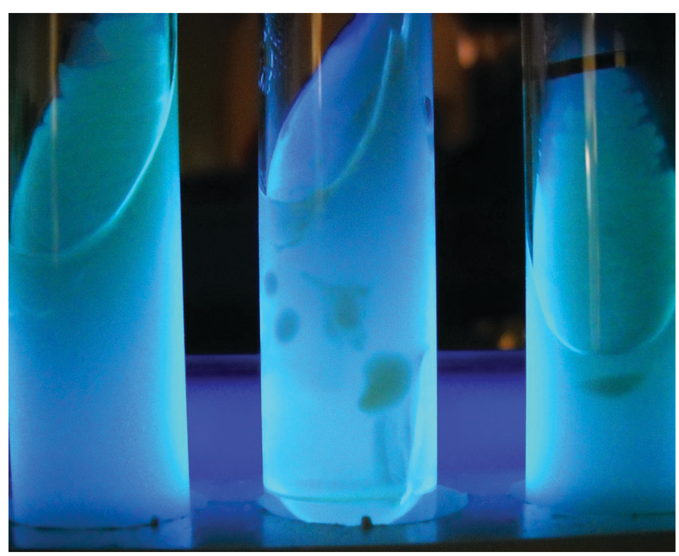


TABLE 1. Results of the water samples collected along the Chicago River.

Water Samples	Location	CFU on MacConkey Agar Plate	Bacterial Identification
Site 1	Goose Island East Side	84,000 /100 mL	***Escherichia coli***
Site 2	Goose Island Northwest Side	21,500 /100 mL	***Enterobacter agglomerans; Escherichia coli***
Site 3	Goose Island West Side	144,300 /100 mL	***Enterobacter gergoviae; Enterobacter agglomerans; Serratia odorifera***
Site 4	Wolf Point	62,000 /100 mL	***Escherichia coli***
Site 5	Locks (near Lake)	6,000 /100 mL	***Enterobacter sp.***
Site 6	Wabash Street Bridge	No CFU Count performed	***Pseudomonas aeruginosa***

the O'Brien Water Reclamation Plant (660 CFUs /100 mL) (MWRD 2011). All sites where students obtained samples are located approximately eight to ten miles downstream from the O'Brien Water Reclamation Plant.

While a total of six sites were randomly selected for this investigation, no specific reports have been found regarding these sites. The implication of the findings is that there is urgent need to make the river safe as a recreational place for Chicago residents.

Discussion

As evidenced by the results, this research focuses on what students can and do achieve when given the opportunity to learn through PBL and undergraduate research. It also demonstrates the ability of undergraduate students at the community college level to give back to society. The central point is the impact of the learning that resulted from this type of civic engagement conducted by undergraduates, including what they could contribute to help the community in making informed decisions related to safety and the quality of the river. This project was part of an interdisciplinary course in which faculty and students at Harold Washington College pursued work on various aspects of the Chicago River. The Chicago Waterways Project, as conducted, provided students with the opportunity to discover by themselves what civic engagement and community service are all about.

The evaluation of students' feedback revealed that appreciation for the project's role in highlighting the significance of the Chicago River and appreciation for being part of something special were the major themes identified. Serving and giving back to the community was another key topic they mentioned. The average retention rate at HWC is 67 percent, in this course a retention rate of 88 percent was achieved. Upon assessment of the members of the microbiology section within this interdisciplinary class, 100 percent of the participants had either successfully transferred as a science major to a four-year institution or had been accepted in professional career programs. The success of this small model has tremendously encouraged us to use PBL with a civic engagement purpose in larger-scale future classes.

As part of this interdisciplinary research project at HWC, the result of this study was presented as a poster that was visited by members from the seven City Colleges of Chicago and the general public. The result was also presented orally to the attendees at the national conferences of the American Association of University Administrators (AAUA) and the Association of American Colleges and Universities (AACU) (Martyn and Movahedzadeh 2014; Martyn et al. 2013).

Given that the EPA aims to make the Chicago River an area designated for primary contact recreational use by 2016, the research project described in this paper had a significant purpose: to enable students from a microbiology research course with a PBL emphasis to develop and complete a project that investigated the contamination of the Chicago River. Through this process, the students were inspired and empowered, recognizing that they had an important role to play both in contributing to the collective body of research focused on the Chicago River's ecosystem and in increasing citizens' awareness of existent public health concerns. The outcome of this research brought valuable results to the populace and invaluable skills to the students, enabling them to demonstrate the intrinsic value of civic engagement.

The water samples collected revealed the presence of enterobacteria in the Chicago River. These bacteria are coliform bacteria, indicating that fecal contamination is likely. Contamination in the water could be due to the fact that currently only three out of seven of Chicago's water reclamation plants disinfect their wastewater before pumping the effluent back out into the area waterways. Furthermore, it is worth noting that none of these three disinfecting plants sit adjacent to the Chicago River or serve the City of Chicago directly; thus these plants' contribution of clean water to the river is not as significant as that of the contaminated sources. The Chicago River is a resource widely used for recreation by local residents and guests visiting Chicago. It is troubling to discover and report such a high number of CFUs. To add some perspective, consider standards applied along the shore of Lake Michigan, another source of recreational water use in Chicago. The Illinois Department of Public Health's regulations contain a maximum standard for fecal coliform bacteria at 500 CFUs /100 mL at area beaches (Illinois Department of Public Health 2015). It is imperative to pay attention to the state of the river's water quality, as new development along the beautified pedestrian walkways attract residents and tourists alike.

Through this research project, students acquired and improved upon skills currently employed in the microbial research/clinical setting. Nevertheless, the skills learned in this project go beyond the mastery of technical skills and practices in the laboratory. This project provided students a chance to further develop skills that will be useful in their future professions and daily lives, such as responsibility, critical thinking, self-motivation, collaboration, and communication. The concepts presented in the classroom and applied in the field fostered a more profound understanding and a greater appreciation of the biological sciences and how they can be applied directly to help address real world issues.

This research project revealed the significant role that technology plays in our society when utilized to address critical problems such as water contamination. It also attests to the importance and the value of civic engagement in college education. Students participating in this PBL course developed a profound personal attachment to effecting positive change in both the environment and their communities. A similar example can be found in a PBL based calculus II course at Roosevelt University, where semester-long projects have been incorporated into the course curriculum. The project topics vary from HIV/AIDs to wealth distribution, and include the mathematical topics being taught in the course. These projects have allowed the students to "understand the quantitative aspects of civic issues using models that rely on calculus for their construction" (González-Arévalo and Pivarski 2013). In addition, students gained an enhanced appreciation of mathematics and its applications in other fields (González-Arévalo and Pivarski 2013). PBL enables students to increase their knowledge while challenging them to think critically and teaching them to design and direct a project of their own. This work unifies the students' initiative to direct their own learning and to accept responsibility for their education. At HWC, PBL had previously been successfully integrated in a biotechnology lab course where students demonstrated a high level of performance and satisfaction (Movahedzadeh et al. 2012). Moreover, students indicated that this experience supported their cognitive development and self-confidence and stimulated the idea of continuing their education beyond the associate degree level (Movahedzadeh et al. 2012). With minimal funding and support, students can be enriched with hands-on knowledge that breaks the traditional forms of teaching. PBL could be used as an effective vehicle guiding students to civic engagement while obtaining the skills needed to succeed in their higher learning and in their future professions through an active connection with their environment.

Interesting results were found testing the water of the Chicago River. Coliforms like *E. coli*, *Pseudomonas aeruginosa*, and the opportunistic pathogens *Enterobacter agglomerans* and *Serratia odorifera* were isolated. Students found it imperative to instruct river enthusiasts and the broader community at large of the existence of coliforms and ways to reduce the risk of infection due to exposure from opportunistic pathogens. Simple precautions recommended to avoid water-borne illness when swimming or playing in or on the water include proper hand washing, showering before and after water exposure, refraining from recreational activities in water that is stagnant with dead fish, refraining from digging in or stirring up the sediment while taking part in water-related activities in shallow and warm freshwater areas, and promptly tending to any wounds, cuts, or abrasions suffered in or near the water (North Carolina Department of Health and Human Services 2011).

The Chicago River has received bad press due to the polluted status of its ecosystem. These findings reveal the importance of seeking solutions to improve the water quality of the Chicago River. This is vital, especially since recreational activities are on the rise along the Chicago River. The solution could be disinfecting the wastewater from all seven reclamation plants before pumping the effluent back into the waterway system. We propose that there should be a collaborative effort that includes students from the City Colleges of Chicago. Instead of wasting materials on lab exercises divorced from real-world applications, students would prefer to assist in efforts aimed at continually improving and monitoring the standards of our communal waterway, having already demonstrated their willingness and competence to do so. Our laboratories are capable of contributing to the success of these efforts.

The primary goal of this research project was to engage students in the learning process and to create an educational environment where meaningful learning was not only possible, but would actually occur. Students explored conceptual meanings and implications throughout the learning processes contained in this PBL course. Furthermore, students gained vital experience by participating in the Chicago Waterways Project, where they applied what had been previously learned exclusively in the didactic classroom. This learning experience was further enriched when students tackled the problem of contamination in the Chicago River, an issue that must be addressed due to its potential to affect public health. It is hoped that this research will motivate students and the public to take action in the restoration of the river. Involving college students in research projects such as these reveals to them the impact they can have on society and how important their participation is in addressing these issues. PBL demonstrates to students that the scholastic subjects they may deem uninteresting or useless play an integral role in addressing the problems of society, in this case, the quality of the Chicago River. With encouragement and minimal financial resources students can gain a world of knowledge beyond the classroom and thrive by applying that knowledge to engage the issues in the world around them.

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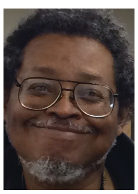

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References

AACC, American Association of Community Colleges. 2010. Fact Sheet. http://www.aacc.nche.edu/AboutCC/Documents/Archive/factsheet2010.pdf (accessed January 24, 2015).

Brickman, P., C. Gormally, N. Armstrong, and B. Hallar. 2009. "Effects of Inquiry-based Learning on Students' Science Literacy Skills and Confidence." International Journal for the Scholarship of Teaching and Learning 3 (2): 1–22.

Brown, J.L. (2002). Reversal of the Chicago River, Civil Engineering, no. 72: 110-111. Retrieved from: Academic Search Complete, EBSCOhost

Chang, C., W. Chen, S. Lou, and K. Tseng. 2011. "Attitudes towards Science, Technology, Engineering and Mathematics (STEM) in a Project-based Learning (PBL) Environment." International Journal of Technology and Design Education 23: 81–102.

Cherif, A., G. Adams, F. Movahedzadeh, M. Martyn, and J. Dunning. 2014. "Why Do Students Fail? Faculty's Perspective." Collection of Papers from the Annual Conference published by the Higher Learning Commission. http://cop.hlcommission.org/Learning-Environments/cherif.html (accessed January 24, 2015).

Cherif, A., F. Movahedzadeh, G. Adams, and J. Dunning. 2013 "Why Do Students Fail?" Higher Learning Commission: A Collection of Papers on Self-Study and Institutional Improvement 29: 35–51.

Doles, K. 2012. "What is Project-Based Learning?" Frontline. PBS. July 17, 2012. Television. http://www.pbs.org/wgbh/pages/frontline/education/fast-times-at-west-philly-high/what-is-project-based-learning/ (accessed January 24, 2015).

Eiseley, L. 1959. The Immense Journey. New York: Vintage Books.

Environmental Protection Agency (2011). Summary of EPA's Actions on Illinois' New and Revised Water Quality Standards for the CAWS and LDPR. (2011). http://www.epa.gov/region5/chicagoriver/pdfs/caws-summary-20120510.pdf

González-Arévalo, B., & Pivarski, M. (2013). The Real-World Connection: Incorporating Semester-Long Projects into Calculus II. Science Education and Civic Engagement 5:1: 17-24. http://seceij.net/seceij/winter13/real_world_conn.html

Hill, L. 2000. The Chicago River: A Natural and Unnatural History. Chicago: Claremont Press.

Illinois Department of Public Health. 2015. Bathing Beaches. http://www.dph.illinois.gov/topics-services/environmental-health-protection/recreation/bathing-beaches (accessed January 24, 2015).

Martyn, M., and F. Movahedzadeh. 2014. "Undergraduate Research: The Final Frontier." Paper presented at the conference of the American Association of University Administrators (AAUA). Washington, DC: April 25–26. http://www.aaua.org/seminar-program-details.htm (accessed January 24, 2015).

Martyn, M., F. Movahedzadeh, and S. Burke. 2013. Chicago Waterways: STEM to STEAM. Paper presented at Transforming STEM Education: Innovation, Inquiry, and Evidence, conference of the American Association of Colleges and Universities: San Diego, October 31–November 2. http://www.aacu.org/events/chicago-waterways-stem-steam (accessed January 24, 2015).

Movahedzadeh, F., R. Patwell, J.E. Rieker, and T. Gonzalez. 2012. "Project-Based Learning to Promote Effective Learning in Biotechnology Courses." Education Research International. Article ID 536024.

MWRD, Metropolitan Water Reclamation District of Greater Chicago. Disinfection Task Force. 2011. Evaluation of Disinfection Technologies for the Calumet and North Side Water Reclamation Plants: Technical Memorandum 2, 4–17.

North Carolina Department of Health and Human Services. 2011. Avoiding Recreational Water Illnesses. http://epi.publichealth.nc.gov/cd/water/prevent.html (accessed January 24, 2015).

Oh, G. 2012. "Coming Clean: Swimmable Chicago River To Become Reality." Medill Reports, Northwestern University.

The State of College & Career Readiness: Part 1. Infographic. 2013. http://www.pearsonlearningsolutions.com/blog/wp-content/uploads/2013/05/college-readiness-infographic3.pdf (accessed January 24, 2015).

Webb, Jeffrey A. 2013. "Integrating SENCER into a Large Lecture General Education Chemistry Course." Science Education and Civic Engagement 5 (2).