PROJECT REPORT

The "Muddy Waters" Environmental Geology Course

Kenneth M. Voglesonger
Northeastern Illinois University

Jean M. Hemzacek
Northeastern Illinois University

Laura L. Sanders
Northeastern Illinois University

Abstract

Teaching geology and its relevance in urban environments is often challenging. "Muddy Waters," a First-Year Experience course for non-majors, uses the concepts of water quality and quantity in an urban environment to introduce current urban environmental geology issues including flooding, wastewater treatment and disposal, and drinking water supply and treatment. Through extensive fieldwork and laboratory work, students investigate these concepts through various extended projects using different themes and then present their results to a variety of audiences. The course utilizes the extensive river and canal system in the Chicago area and topics of current interest to engage learners in the environmental geology that may go unnoticed by the majority of our urban students. Results show that students become more aware of where their drinking water comes from, what happens to wastewater, the severity and frequency of flooding, and engineering techniques implemented to lessen the impacts of flooding in surrounding neighborhoods.

Introduction

Connecting urban students to the geological aspects of their environment can be challenging—more or less so, depending on the geographic setting. In the geologically "plain" setting of Chicago, where there are few visual indicators of geology, students generally lack awareness of, and therefore interest in, the natural processes that shaped their environment. Add to this a public school system that only rarely offers high school earth science courses, and the result is geologically and in turn environmentally disconnected students. At Northeastern Illinois University (NEIU), in northern Chicago, this disconnect from the physical environment may be compounded by student demographics. Nearly 50 percent of incoming freshman are Hispanic, a population traditionally underrepresented in geology and STEM disciplines. About fifty-three percent are first-generation college students. Most do not have role models who have been exposed to the existence, importance, or relevance of career opportunities within the geosciences or STEM and therefore do not readily choose Earth Science as a major (see Table 1.)

TABLE 1. Total Enrollments and Bachelor Degrees Conferred at NEIU (Number of Students)

		Total Undergraduate Enrollment		Bachelor's Degrees Conferred	
		University	Earth Science Majors	University	Earth Science Majors
2011-2012	White	4566	31	839	2
	Black	1156	2	147	0
	Hispanic	3526	11	428	0
	Asian/ Pacific Islander	1098	3	157	0
	Amer Indian/AK Native	27	1	7	0
	First-Generation College	5167	26	NA	NA
2012-2013	White	4358	29	778	4
	Black	1186	2	157	0
	Hispanic	3614	18	404	0
	Asian/ Pacific Islander	1078	4	168	0
	Amer Indian/AK Native	23	1	3	0
	First-Generation College	5715	33	NA	NA
2013-2014	White	4018	24	796	5
	Black	1121	2	149	0
	Hispanic	3590	18	420	1
	Asian/ Pacific Islander	1071	3	184	2
	Amer Indian/AK Native	25	0	2	0
	First-Generation College	5906	31	NA	NA
2014-2015	White	3659	24	796	5
	Black	1050	3	143	0
	Hispanic	3510	19	446	4
	Asian/ Pacific Islander	1035	1	165	0
	Amer Indian/AK Native	24	0	3	0
	First-Generation College	5542	33	NA	NA

We attempted to address these issues by creating and implementing a First-Year Experience (FYE) Program course titled *Muddy Waters: Chicago's Environmental Geology* (ESCI 109W). Like all courses in our FYE Program, the course integrates discipline-specific content (e.g. urban environmental geology) with college success skills (e.g. time management). Discipline-specific content of Muddy Waters focuses on water quality and quantity issues that are timely and relevant in a city where rivers and lakes are key features. Using themes of water quality and quantity, we developed field and laboratory activities designed to build a sense of connection to the Chicago area while addressing current and relevant environmental issues. The course involves extensive hands-on experiences highlighting human impact in an urban environment connected to geology. All class projects are set in the Chicago area, primarily the local neighborhood; field activities, laboratory work, and collection and interpretation of online data address specific content-related areas of interest.

Course Design

We designed the course to provide students with a sense of how urban environmental geology is relevant to their lives and to the city in which they live. Given the diverse makeup of first-year students at NEIU, course elements also aim to increase diversity within the geosciences and STEM disciplines. Through the design and delivery of the course, we strive to help students understand that a career in geology is a legitimate, relevant, exciting, accessible, and attainable goal.

Specific course objectives are that students will learn to do the following:

1. Compile an organized record of data and supporting information from various sources (field, laboratory, class presentations, readings, research), optimized for the student's individual learning style.
2. Distinguish landscape changes effected by stream, lake, and coastal processes; critically analyze patterns of change in water bodies to predict continuing/ future changes.
3. Evaluate the impact of geologic factors on human activities in Chicago (water and waste management, stormwater and sewage treatment/control, construction, etc.) and the effect of human activities on analyzed parameters of water quality and quantity.
4. Apply identified strategies to maximize student achievement of short-term and long-term academic goals through self-knowledge, navigating the university environment, and effective planning.

Here we present the course structure, highlighting activities designed to achieve the course objectives and goals.

Course Projects

The course is structured around five main projects through which students engage in learning activities that provide them with exposure to relevant geological issues and opportunities to learn content and skills and to practice applying what they learn as they work to complete the projects. The identified projects are titled "Chicago Rivers," "Thirsty City," "The Great Debate," "H2O: Where Does it Go?," and "The Balancing Act." The project-based learning strategy provides students opportunities to actively explore real-world problems, work collaboratively, and become personally engaged with the material. The approach challenges them to think critically and gain a new appreciation of the role of geology in their own lives (Movahedzadeh et al. 2014). The projects incorporate group work (McConnell et al. 2005), role-playing and debate (Gautier and Rebich 2005), experience-based learning (Apedoe et al. 2006), and a variety of presentation modes (poster, oral, peer review) as methods to engage the students.

Collaborative learning activities influence "how students think," promoting development of higher-order thinking skills and improvement of reasoning among nonmajor students in introductory geoscience classes (McConnell et al. 2005). "Overwhelmingly favorable" changes to student performance on learning outcomes were reported by Apedoe et al. (2006) for a geoscience course utilizing inquiry-based pedagogy, but they also acknowledged initial challenges for students in adjusting to their more active role, compared to a teacher-centered classroom. The Muddy Waters course utilizes discovery, balanced with guidance and instructor support particularly at the start of the term, to familiarize students with this role. Gautier and Rebich (2005) demonstrated improved student learning outcomes with respect to complex systems, such as the urban Chicago hydrologic system that is the focus of the Muddy Waters course, through a learner-centered environment that includes role-playing and group work. Their assessment of a "Mock Environmental Summit" showed enhanced student learning of content and critical skills and improved presentation skills, while fostering civic engagement with an issue: all of these are goals built into the project constructs of the Muddy Waters course.

Chicago Rivers

NEIU is located in the Albany Park neighborhood of Chicago, prone to flooding by the North Branch of the Chicago River. One-hundred year flooding events in 2008 and 2013 resulted in closure of NEIU's campus and surrounding streets. Students visit the river and measure stream velocity and discharge. One exciting aspect for the students is the opportunity to directly wade into the river to take measurements. Students visit a nearby stream gage operated by the U.S. Geological Survey and later collect data from that gage and others in the region.

Through these activities, students are exposed to methods and equipment directly related to phenomena that impact the community. They become aware that streamflow monitoring and flood-prevention strategies are occurring right under their noses. As a final product, students collect online data on streamflow, create

FIGURE 1. Student measuring stream discharge in the North Branch of the Chicago River .

flood-frequency curves, calculate probabilities and discharges for flows of different recurrence intervals, and examine Flood Insurance Rate Maps for a specific area. Students present a poster that includes their results along with recommendations for reducing or minimizing flood damage.

Thirsty City

In this project, student teams investigate Chicago's municipal water system from drinking water source to wastewater discharge. Many students confuse the role of Lake Michigan (the regional source of drinking water) and roles of the local river/canal system (removal of treated wastewater). Questions posed address where our drinking water comes from and how it is treated to make it potable, what happens to wastewater/sewage and how it is treated before if it is discharged to local waterways, and where the treated wastewater goes after it leaves the Chicago area. Field sites include Lake Michigan beaches and the discharge point of treated wastewater into a canal. Students collect samples for analysis and make field measurements of pH, dissolved oxygen, total dissolved solids, and temperature from both field sites. They learn basic laboratory methods and colorimetric techniques to measure sulfate, chloride, nitrate, phosphate, and fluoride in their samples and then analyze tap water to see if drinking water treatment affects these parameters. Students compare their results to maximum contaminant levels (MCLs) set by the U.S. Environmental Protection Agency. As a final product, teams present posters displaying results of their measurements along with research on a specific aspect of the water treatment process (e.g. fluoridation, primary wastewater treatment, secondary treatment) assigned to each team. The resulting poster session is structured so that visitors begin by viewing posters describing the drinking water source and end with wastewater treatment and discharge, simulating the flow through the municipal water system.

The Great Debate

Current local issues are used to engage students in scientific exploration and inquiry related to a real-life matter of contention. Examples of recent topics have included, "Should the City of Chicago disinfect treated wastewater?" and "Should flow of the Chicago River be restored to its natural direction, towards Lake Michigan?" This project is often jump-started by current news stories or opinion articles. The class is divided into teams representing different perspectives on the question. Each team is assigned the role of a type of organization chosen deliberately to represent the competing and various interests represented in modern day environmental issues: governments concerned about revenue and costs (e.g. City of Chicago), advocacy groups focusing on sustainability and protection of natural resources (e.g. Friends of the Chicago River), regulatory agencies (e.g. U.S. Environmental Protection Agency), municipalities impacted by the issue (e.g. downstream locations), or those organizations directly involved (e.g. Metropolitan Water Reclamation District). Using previously gained knowledge, students investigate each side of the issue and collect data to formulate and support their arguments. Questions outlining the topics are provided to launch the research. For example, in the debate over disinfection, students were given these prompts:

1. Draw a flow chart illustrating how water from Lake Michigan may end up in the Mississippi River and the Gulf of Mexico.

2. Describe eutrophication, and explain its relationship to discharge of wastewater and the Gulf of Mexico Dead Zone.
3. Illustrate the basic steps in sewage treatment.

The project culminates in a formal, structured, in-class debate that is evaluated with a rubric for the factual content of arguments, logical presentation, and communication skills.

H2O: Where Does It Go?

This project addresses water usage and water management on the NEIU campus. Groups of students play the role of environmental consulting firms, hired by the campus Facilities Management office to assess tap water usage, wastewater generation and management, and stormwater management. Students are tasked with creating a professional-looking consulting report with suggestions on how to do the following:

1. Minimize the quantity of tap water used on campus.
2. Minimize the quantity of water exiting campus through sanitary sewers.
3. Minimize the quantity of water leaving campus through stormwater runoff.

To introduce the project, students are led on a field trip throughout the campus and asked to identify how water, specifically stormwater runoff, moves through different areas of campus (parking lots, grassy areas, storm sewers, detention basin). Students are introduced to concepts of infiltration and surface runoff through a discussion of the hydrologic cycle within their urban environment, emphasizing both natural and anthropogenic aspects. Another campus field trip identifies locations of underground water vaults at points where the city tap water enters the campus and initiatives designed to better manage stormwater, such as sections of permeable pavement and native vegetation plantings. Involving the campus Chief Engineer, who participates in the field trips and provides a new perspective on the nuts and bolts of the institutional efforts to manage water, especially engages students with this real-life issue on their campus.

As part of their consulting report, students must provide data on quantities of tap water used by NEIU, water precipitating on campus, and water leaving campus through storm sewers each year. Students collect annual precipitation data from the NOAA website and calculate campus area using maps. They then calculate total volume of precipitation, requiring unit conversions and understanding the difference between linear, areal, and volume measurements. The final report includes data on water usage and management as well as descriptions of how tap water is used, where sanitary sewage is produced, and what happens to precipitation that falls on campus, along with the students' recommendations on minimizing tap water usage, minimizing wastewater production, and minimizing the stormwater leaving campus. Given the level of mathematics required for this project and the level of math proficiency of incoming students, this is a very challenging project. Our goal is that students see how mathematics and science are utilized on their own campus, for an issue in which they have a personal stake.

The Balancing Act

In the final project of the course, students calculate annual water budgets for local watersheds. Building on concepts learned in "H2O: Where Does It Go?" and "Chicago Rivers," this project challenges students with calculations of area and volume, unit conversions, and gathering and analyzing actual data. Students are assigned a watershed, a NOAA precipitation gage, and a USGS stream gage from which to gather online data. They calculate the total amount of water entering the watershed as precipitation and the total amount of water leaving the watershed as streamflow. They also are provided with total population and per capita water usage for their assigned watershed, with some notes on the sources of municipal water for the basin (for example, inter-basin transfer or ground water wells). A worksheet is provided to guide students as they organize and calculate inflows and outflows, and they are asked to fill in blanks with their calculated results for each component of the water budget. Students are prompted to calculate the yearly amount of evapotranspiration, which is not available online but must be estimated using inflow and outflow data; the value for evapotranspiration is used to balance the water budget.

TABLE 2. Continuation and Graduation Rates of First-Time Freshman at NEIU who took ESCI 109W, a Different FYE Course, and No FYE Course At All

					Continuation and Graduation Rates							
Cohort Entry Term	FYE Enrollment Status	Head Count	Average ACT	% STEM Major	% Continued to Spring of Year 1	% Continued to Year 2	% Continued to Year 3	% Continued to Year 4	% Graduated by Year 4	% Continued to Year 5	% Graduated by Year 5	% Continued to Year 6
Fall 2010	Enrolled in ESCI-109W	26	19.7	19%	81%	58%	39%	35%	8%	35%	23%	15%
	Enrolled in other FYE courses	767	18.9	11%	89%	68%	49%	43%	4%	37%	15%	23%
	Not enrolled in any FYE courses	248	18.9	4%	62%	45%	29%	26%	2%	20%	8%	15%
	Total	1041	18.9	9%	82%	62%	44%	39%	4%	33%	14%	21%
Fall 2011	Enrolled in ESCI-109W	58	18.3	24%	98%	81%	60%	50%	3%	36%	3%	
	Enrolled in other FYE courses	665	19.0	11%	88%	64%	50%	43%	4%	37%	4%	
	Not enrolled in any FYE courses	226	19.4	7%	60%	46%	34%	27%	3%	21%	3%	
	Total	949	19.0	11%	82%	61%	47%	40%	4%	33%	4%	
Fall 2012	Enrolled in ESCI-109W	33	18.3	27%	88%	49%	42%	33%				
	Enrolled in other FYE courses	715	18.7	10%	87%	68%	50%	43%				
	Not enrolled in any FYE courses	291	18.4	6%	53%	40%	30%	24%				
	Total	1039	18.6	9%	78%	60%	44%	37%				
Fall 2013	Enrolled in ESCI-109W	24	19.8	8%	88%	58%	46%					
	Enrolled in other FYE courses	645	18.7	11%	85%	62%	46%					
	Not enrolled in any FYE courses	139	19.4	6%	50%	44%	33%					
	Total	808	18.8	10%	80%	59%	44%					
Fall 2014	Enrolled in ESCI-109W	13	21.1	0%	85%	62%						
	Enrolled in other FYE courses	620	18.8	9%	83%	62%						
	Not enrolled in any FYE courses	137	18.1	5%	68%	47%						
	Total	770	18.8	8%	80%	59%						
Fall 2015	Enrolled in ESCI-109W	23	18.4	4%	74%							
	Enrolled in other FYE courses	516	18.4	2%	83%							
	Not enrolled in any FYE courses	210	17.9	3%	75%							
	Total	749	18.3	3%	80%							

Notes: 1) FYE course enrollment status was based on any FYE enrollment during the first year in college.
2) Percent of students with a declared major in STEM is based on the latest major on record as of March 2016.

Conclusion

Using a SENCER approach that considers a variety of community-related issues, we created a course that teaches fundamental scientific concepts, develops critical thinking and analytical reasoning skills, connects students to their community, and increases students' awareness of the geologic world around them, specifically in the urban environment of Chicago. Development and implementation were initially funded by a grant from the National Science Foundation (Award # 0914497), and the course has been successfully institutionalized. It has been taught ten times between 2010 and 2015, to a total of 159 students, and continues to be a popular course within our curriculum.

Initial analysis of data on the retention of students who have taken the course (compared to students who took a different FYE course and those who took none at all) is presented in Table 2. Also shown are the percentages of students in these groups who have declared a major in a STEM field, and graduation rates. With the smaller pool of students who have taken Muddy Waters, we expect to see the variation shown in the data. We also have considered the relative difficulty of a natural science laboratory course for first-year students compared to other non-STEM FYE courses. Further analysis of these data, including a separate accounting for retention of STEM majors, a comparison of the courses taken by Muddy Waters students following this course with those taken by other students, and demographic analysis is warranted to further explore the trends and variation seen here.

Given the nature of the course, there are particular challenges that we encountered in its design, implementation, and delivery. Some of these challenges are those that are common to many First-Year Experience courses (e.g. delivering content-related material at an appropriate level, incorporation of student success skills training). Challenges specific to this laboratory course in the natural sciences include

1. Generating and capturing student interest by making the projects personally relevant to a diverse body of students.
2. Engaging students who have a wide range of mathematical, reading, and writing preparation and skills.
3. Given the large amount of group work and cooperative learning, assembling groups with positive dynamics that represent the wide variety of preparation mentioned above and providing all of the students with the opportunity to learn from each other.
4. Determining the scaffolding of mathematical skills appropriate for the projects in order to support student success.
5. Overcoming the initial hesitation on the part of the students to some of the field activities. (This hesitation quickly abated after the first field sessions for the most part.)
6. Handling the logistics involved with transportation and access to field sites.

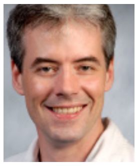
Moving forward, we continue to modify the course to keep the topics current and, what is even more important, personally relevant to the students. Along with this we will continue to develop the skill sets needed by the students to successfully complete the course. We continue to seek innovative and novel ways to increase the relevance of geoscience and STEM-related professions and academic tracks. Another outcome of the course was the expressed desire of our Earth Science majors to have us offer them a similar course at a major level, especially once they observed the field and laboratory activities that were central to the course. We plan to develop such a major-level course in the future. We have successfully used Muddy Waters as a recruitment pool for research opportunities geared for early-career undergraduate students (USDA-NIFA Hispanic-Serving Institutions Grant Program Award # 2010-02071) and are currently preparing a manuscript on these results. Overall, we will continue to focus on methods and approaches to increase the participation of underrepresented groups in the STEM disciplines, and more specifically in the geosciences.

Acknowledgments

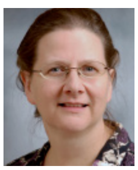
We are grateful for the support of Assistant Provost of Student Success and Retention Barbara Sherry and the First-Year Experience Program at Northeastern Illinois

University. We also thank Hoa Khuong and Blase Masini of the Office of Institutional Research and Assessment for providing data on enrollments, continuation, and graduation rates. This work was funded by a grant from the National Science Foundation (Award # 0914497).

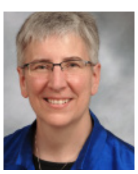
About the Authors



*Kenneth M. Voglesonger** (Ph.D. Geology) is an Assistant Professor and Department Coordinator of the Earth Science Department at Northeastern Illinois University. His areas of expertise are aqueous geochemistry, geomicrobiology, and hydrothermal geochemistry. He is currently involved in numerous initiatives to increase the participation of underrepresented minorities in undergraduate research and in the geosciences in particular.



Jean Hemzacek (M.S. Geology) is an Instructor of Earth Science at Northeastern Illinois University, with areas of expertise and experience in clay minerals, mineralogy, and soil science. Her move to teaching followed a career of mineral research and applications in the mining industry. She is passionate about student engagement in STEM and innovative pedagogies to enhance learning, from first-year experiences through advanced research opportunities for STEM majors.



Laura L. Sanders (Ph.D. Applied Geology) is Professor of Earth Science at Northeastern Illinois University, with areas of expertise in hydrology, ground water geology, and environmental geology. In 30 years of teaching at Northeastern, she has directed dozens of master's theses and scores of undergraduate research projects. She is a recent U.S. Department of Agriculture E. Kika de la Garza Fellow.

References

Apedoe, X.S., S.E. Walker, and T.C. Reeves. 2006. "Integrating Inquiry-based Learning into Undergraduate Geology." Journal of Geoscience Education 54: 414–421.

Gautier, C., and S. Rebich. 2005. "The Use of a Mock Environmental Summit to Support Learning about Global Climate Change." Journal of Geoscience Education 53: 5–16.

McConnell, D.A., D.N. Steer, K.D. Owens, and C. Knight. 2005. "How Students Think: Implications for Learning in Introductory Geoscience Courses." Journal of Geoscience Education 53: 462–470.

Movahedzadeh, F., A. Linzemann, E. Quintero, J. Aveja, W. Thompson, and M. Martyn. 2014. "Life in and around the Chicago River: Achieving Civic Engagement through Problem Based Learning." Science Education and Civic Engagement: An International Journal 7 (1): 35–41.