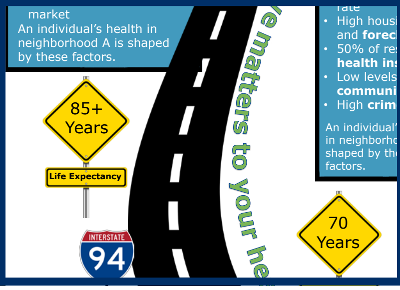

SCIENCE EDUCATION & CIVIC ENGAGEMENT

AN INTERNATIONAL JOURNAL

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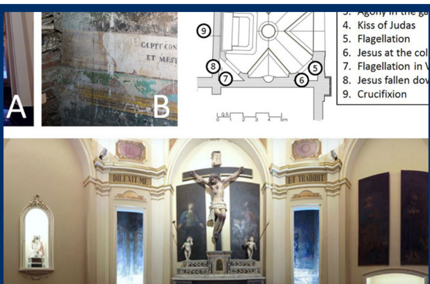


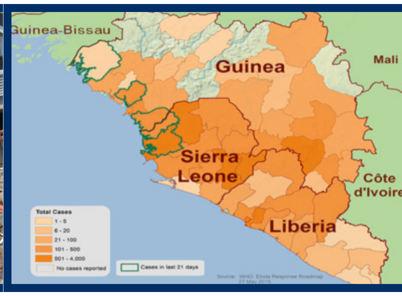

About the Journal

Science Education and Civic Engagement: An International Journal is an online, peer-reviewed journal. It publishes articles that examine how to use important civic issues as a context to engage students, stimulate their interest, and promote their success in mathematics and science. By exploring civic questions, we seek to empower students to become active participants in their learning, as well as engaged members of their communities. The journal publishes the following types of articles:

- *Book & Media Reports*
- *Point of View*
- *Project Reports*
- *Research*
- *Review*
- *Science Education & Public Policy*
- *Teaching & Learning*

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From the Editors

The Winter 2016 issue of *Science Education and Civic Engagement: An International Journal* is the first published by the National Center for Science and Civic Engagement through its new institutional affiliation with Stony Brook University. We are pleased by the range and diversity of the civic issues addressed by articles, and in particular, by the strong representation of interdisciplinary and trans-departmental collaborations, including several that integrate content from STEM disciplines with material drawn from the humanities and visual arts.

The connection and relevance of science to the fine arts, and of both to our civic and social well-being, to is foregrounded in two project reports. "The Link between Science and the Humanities" by Paula Bobrowski and Ann Knipschild, of Auburn University, describes an innovative course where students learn and conduct research on music and the science behind its effects on the human body and brain—effects with important therapeutic implications for physical and emotional ailments. Physicist Antonino Cosentino reports on the low-cost technology and investigative methods he has developed for students of archaeology, art history and art conservation in "Scientific Examination of Cultural Heritage Raises Awareness in Local Communities." Cosentino argues that the preservation and conservation of cultural heritage material is a matter of increasing civic importance, particularly in communities where public resources are scarce, Addressing this challenge will demand multi-disciplinary competence in science, technology, history, and art, as well as the creative application of low-cost and accessible technology.

Debby R. Walser-Kuntz and Cassandra Bryce Iroz have integrated visual literacy goals into a multidisciplinary and experiential learning course on public health by incorporating curatorial and exhibit design strategies. Following a period of community-based work with public-health providers, students partnered with a professional curator and developed a public exhibition, undertaking many tasks required of museum professionals, including brainstorming, identifying key themes and audiences, designing visual presentation strategies, and refining the core content.

A team of authors from the University of North Carolina-Asheville argue for the significant gains that interdisciplinary collaborations around important civic questions can offer both students and faculty in "Why We Should Not 'Go It Alone': Strategies for Realizing Interdisciplinarity in SENCER Curricula." Reporting on a coordinated curriculum design initiative on the theme of "Food for Thought," which shared learning outcomes across multiple courses and departments, the Asheville team reviews the challenges, methods, and findings of this ambitious project.

Habiba Boumlik, Reem Jaafar, and Ian Alberts chose the interdisciplinary implications of STEM learning itself as their pressing civic question in "Women in STEM: A Civic Issue with an Interdisciplinary Approach." They describe a trans-departmental collaboration (Mathematics, Natural Sciences, and Liberal Arts) in a community college that used the question of women's lack of representation in STEM fields as the basis of a course that advanced quantitative literacy, expository writing, and research skills, while increasing student awareness of this important issue.

Environmental issues, and climate change in particular, continue to generate creative curricular responses that reveal the power of students to contribute to public knowledge. "Storm Impacts Research: Using SENCER-Modeled Courses to Address Policy," by Michelle Ritchie and James F. Tait details how the coastal impact of hurricane Irene and Superstorm Sandy offered a unique opportunity for organizing undergraduate research. Students from "Science and the Connecticut Coast" (a 2007 SENCER model) joined with students from other courses that teach environmental science "through" issues of civic consequence. Their combined research on coastal vulnerability and produced policy recommendations to increase the state's coastal resilience in the face of future storms.

Alison Olcott Marshall and Kelsey Bitting at the University of Kansas describe their revision of an existing paleontology course for non-majors, which covered 3.5 billion years of earth's history, by relating the content to complex, controversial and current issues of immediate concern to students. "Teaching Through Human-Driven Extinctions and Climate Change: Adding Civic Engagement to an Introductory Geology Course for Non-Majors" contextualized the pre-historic geologic record, including extinctions, by showing interweaving it with, and showing its relevance to, the understanding of contemporary climate change and the looming prospect of new human-caused mass extinctions.

As we face yet another unanticipated epidemic in the Zika virus, Abour H. Cherif, Jasper M. Bondoc, Ryan Patwell, Matthew Bruder and Farahnaz Movahedzadeh developed a learning activity that helps students understand epidemics and the immensely complex and unsolved scientific and policy challenges they present to human life and society on a global scale. "The Use of Untested Drugs to Treat the Ebola Virus Epidemic: A Learning Activity to Engage Learners" describes a course that included basic biology and epidemiology content, library research, literature review, and collaborative group work. Students were charged with developing an informed and well-supported position, which they debated with peers, on the use of untested drugs on infected patients during a global health crisis.

We hope you will find this collection of reports from the field informative, and as confirmation of the enduring and generative educational experiences that result from teaching science through real and relevant issues of significance for us all.

— *Trace Jordan*
Eliza Reilly
Co-Editors-in-Chief

TEACHING AND LEARNING

Students as Curators: Visual Literacy, Public Scholarship, and Public Health

Debby R. Walser-Kuntz
Carleton College

Cassandra Bryce Iroz
Carleton College

Visual Literacy and Science

Visual literacy is a set of abilities that enables an individual to effectively find, interpret, evaluate, use, and create images and visual media. Visual literacy skills equip a learner to understand and analyze the contextual, cultural, ethical, aesthetic, intellectual, and technical components involved in the production and use of visual materials. A visually literate individual is both a critical consumer of visual media and a competent contributor to a body of shared knowledge and culture (Hattwig et al. 2012, 62).

Designing a public exhibition is one way for students to meet the goals of the Visual Literacy Competency Standards for Higher Education quoted above. Students able to combine visual literacy with strong writing will be better prepared "to function creatively and confidently in the working environments of the twenty-first century" (Weber 2007). Scientists rely on visual images, animations, and 3D models to convey research findings and concepts, yet educational research shows that students "do not necessarily automatically acquire visual literacy during general instruction," but must be explicitly taught these skills (Schönborn et al. 2006). Exhibition design provides a powerful pedagogical approach, helping students learn to "author" in a manner distinct from traditional writing.

Libraries and museums "educate and inform the public about the subject of the exhibit in a balanced and usually unbiased way" (Walbert 2004) and expand the general public's "engagement with and understanding of" a topic (Smithsonian Institution 2002). In order to successfully engage people of all backgrounds, exhibit designers must focus on and carefully consider their audience (Smithsonian Institution 2002). Producing such exhibits encourages students to think creatively and to practice a range of skills, including critical thinking, problem solving, research, teamwork, goal setting, and technological literacy (Walbert 2004). Further, exhibitions that are interdisciplinary, such as those dealing with public health, require students to "apply skills or investigate issues across many different subject areas or domains of knowledge" (Great Schools Partnership 2014). Because the final product involves everyone, students must articulate their ideas and defend their choices in an iterative process (Great Schools

Partnership 2014). This group approach requires students to work in a multi-member team resembling what they may encounter in a future career (Smithsonian Institution 2002). In addition to developing collaborative skills, increasing visual literacy, and fostering innovation, exhibition design assignments increase student engagement with course content and "facilitate student expression in media that are not purely textual" (Lippincott et al. 2014).

Exhibition Design as a Teaching Strategy: Students as Curators

We incorporated a public exhibition as a final project for *Public Health in Practice*, a program novel in its design of combining domestic study away with local academic civic engagement (ACE) projects (Walser-Kuntz and Iroz 2015). Students enrolled in an introductory course to learn about public health models, best practices for working with and in a community, and effective communication of health messages. They then studied off campus for two weeks in both the state's and nation's capital cities and participated in a follow-up course back on campus; it was in this final course that students developed the exhibition. Inspired by the Association of Schools and Programs of Public Health "This is Public Health" campaign, we titled our exhibit "This is Public Health: Public Health in Practice." The goals of the exhibit included (1) sharing our experience with the broader campus, (2) educating others on important aspects of public health, and (3) exposing students to a career field they might be interested in pursuing. As public health is an interdisciplinary field, we aimed to show how it is approached from multiple angles and how all students, regardless of major, might participate. The central location of the library—both geographically and intellectually—allowed students, faculty, staff, and visitors the opportunity to explore the exhibit.

Throughout the process, students engaged in many tasks required of professional museum exhibition curators, including brainstorming, identifying key themes, and thinking about audience "take aways," all while presenting a balanced view (Walbert 2004). To guide the process, the class partnered with the library curator; partnering made the endeavor "less risky" and more successful, as we were new to exhibition design as a pedagogical approach

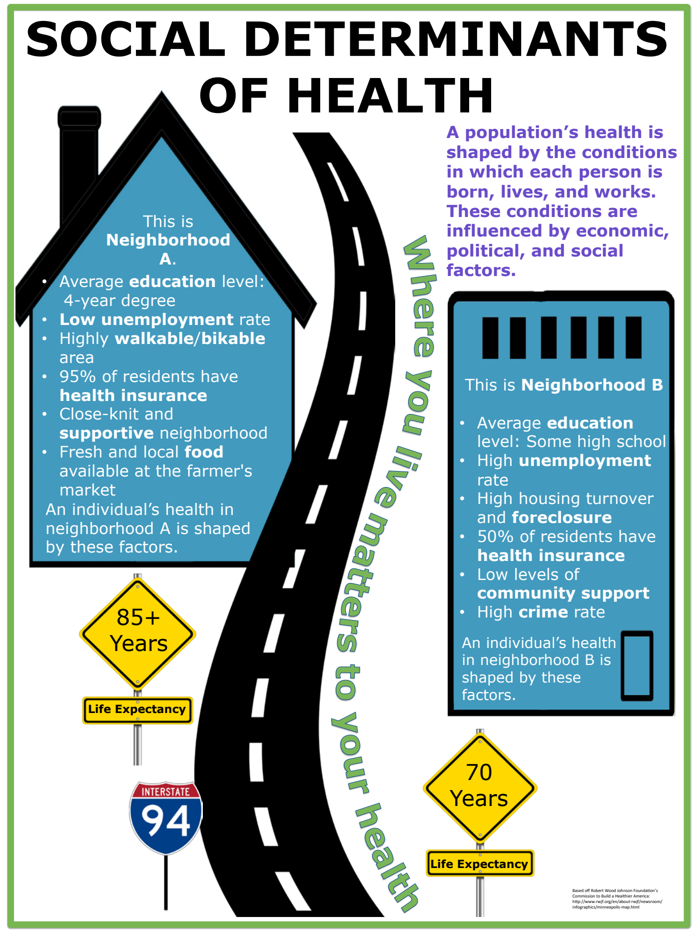

FIGURE 1. Social Determinants of Health

(Lippincott et al. 2014). While the librarian's expertise in visual design and exhibit planning was invaluable, she was new to public health concepts and thus provided an important perspective. She helped us balance detail and eliminate jargon that we had become accustomed to using in our own conversations with one another and with public health professionals.

Although the curator served as a consultant, the students built the exhibition from the ground up with few imposed guidelines or restrictions and took on all the typical roles required for successful execution of an exhibit. These roles include curator (responsible for the overall concept of an exhibit), designer (ensuring the material is understandable, visually appealing, and coherent), and educator (linking content to the audience) (Smithsonian Institution 2002). The entire process encouraged students to reflect on their learning, synthesize and simplify concepts for a general audience, and consider topics from a different perspective. The iterative process of designing the exhibition required a constant review and refinement of ideas, forcing a concise articulation of key points and a clear rationale for the inclusion of an image or design feature. Fonts and color choices received close scrutiny, and the final product required open discussion and compromise. We invited our our academic technologist specializing in presentation and visual design to walk through a mockup of our exhibit and give feedback on images, written messages, and the overall feel of the exhibit. This formative assessment activity continued "the exciting dialogue between exhibit makers and exhibit users" and improved the final exhibit (McLean 1993).

Exhibition Design as a Teaching Strategy: Student Outcomes

Planning the exhibit met the visual literacy competency standard number six: the visually literate student designs and creates meaningful images and visual media (Hattwig et al. 2012). Learning goals met by each student included producing visual materials for scholarly use, using design strategies and creativity in image production, experimenting with image-production tools, and revising work based on evaluation (Hattwig et al. 2011). It allowed us to authentically return to "communicating health messages," a topic covered earlier through research projects, classroom activities, and visits with public health professionals. One particular classroom activity required students to select, analyze, and present an infographic while the class discussed its effectiveness. Infographics are tools frequently used to disseminate public health information to a general audience; thus this media format served as inspiration for the exhibit design. On our study away, students visited with a science museum curator who shared the importance of considering the cultural and educational backgrounds of a diverse audience when communicating and translating science. This visit informed students as they curated, designed, and made decisions about the educational content of their own exhibit.

Student ownership of the project was strong; their investment throughout the process resulted in lively class discussions as we planned, compromised, and refined. The exhibit-planning process encouraged students to reflect on their experiences and synthesize all they had learned through their coursework, study away, and ACE projects into clear, concise messages for the public. In addition to gaining enhanced visual literacy and collaboration skills, their understanding of the core concepts of public health increased. Being forced to articulate complex public health models and approaches in a single sentence required a high degree of understanding (Figure 1). On occasion, students struggled with whether or not to include certain topics or images as they recognized the potential harm. This sophisticated understanding of the ethical implications of their exhibit addressed standard seven of the visual literacy standards as students followed "ethical … best practices when…creating images"; it further demonstrated how each student had become "a competent contributor to a body of shared knowledge and culture" (Hattwig et al. 2011; Hattwig et al. 2012).

Exhibitions and Civic Engagement

Our public health program emphasized working with community. To include visitors in our exhibit we included a large rolling white board with the prompt "What is public health to you?" Visitors left comments and we took photos throughout the exhibit to capture their responses. Anecdotally we heard that many students, faculty, and staff visited and enjoyed the exhibit; we did not, however, formally assess visitor outcomes. In the next iteration of the course, we will incorporate an additional "prototype" step in which we invite students from another course to provide feedback. Although the exhibit is no longer installed, it exists online with an additional interactive component (http://apps.carleton.edu/ccce/issue/health/public-health-in-practice/).

The *Public Health in Practice* exhibition provided a novel way to incorporate public scholarship into a course. A recent survey of liberal arts faculty indicates that an exhibition is a well-understood form of public scholarship and one that is highly regarded (Christie et al. 2015). In our case, the infographic-style posters educated visitors about important aspects of public health, while highlighting the field's breadth and interdisciplinarity and raising awareness of related careers; the exhibit thus addressed the Institute of Medicine's recommendation that all undergraduates learn about public health

(Petersen et al. 2013). Although our exhibit focused on public health, most science courses touch on topics that could become the basis for interesting and educational exhibits that provide an enriching opportunity for students and public audiences alike.

About the Authors

Debby Walser-Kuntz (dwalser@carleton.edu) is a Professor of Biology and the Broom Faculty Fellow for Public Scholarship at Carleton College in Northfield, MN. Debby received her Ph.D. in immunology from the Mayo Graduate School in Rochester, MN. Her research focuses on the impact of environmental factors, including the plastics component bisphenol-A and a high fat diet, on the immune system. She ventured into the world of academic civic engagement more than ten years ago after recognizing that her bright and talented students could still learn, and in fact might learn more, while sharing their knowledge with others.

Cassandra Iroz is a 2014 graduate of Carleton College with a B.A. in Biology. After graduation, she worked as an educational associate in Carleton's Center for Community and Civic Engagement and as the teaching assistant for the Public Health in Practice program. In this role she assisted in organizing and facilitating coursework, travel, and community based academic civic engagement projects all relating to public health.

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PROJECT REPORT

Music: The Link between Science and the Humanities

Paula Bobrowski
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Auburn University

Abstract

"Music and Science" is a course designed specifically to foster the integration of STEM and the humanities and to incorporate an undergraduate research project into a general education class. In addition to studying theories presented in readings, class activities include lectures, video presentations, case study discussions, guest speakers, listening experiences, and a significant team-based undergraduate research project. Students learn how concepts in science and music are intertwined while engaging in actual research that demonstrates the physical and emotional effects that music has on the human body. Students are able to make important connections that show how music can be used for different types of therapies and how it can be used to improve one's quality of life. Preliminary findings based on student feedback and SALG assessment (Student Assessment of Their Learning Gains) indicate that the research project has a significant impact on student learning, interest in science and music, and acquisition of career skills.

Introduction

In response to the need for new courses with innovative teaching strategies, faculty at Auburn University developed a "Music and Science" general education course to promote the integration of STEM and the humanities. This class is intended to develop students' interest and engagement in music and science in order to enhance their understanding of the connection between the two disciplines throughout history and in today's world. We used several class activities to actively engage the students during the course, including guided listening exercises, concert experience analysis, and an experiential learning based research project. A primary goal of adding the research project was to provide the students with a deeper understanding of research methodology, physiology, the neuroscience of music, and how the use of music can be designed into settings to improve one's quality of life. Undergraduate research projects have been found to improve the learning experience in general education courses and may also help students as they prepare for careers in today's world (Cerrito 2008). The purpose of this article is to summarize the Music and Science course and encourage others to develop programs that nurture and advance the integration of STEM and the humanities.

Music is culturally understood by all people and has been an integral part of society since our origins. According to neuroscientist Daniel Levitin (2006), human beings in all civilizations have personal identities that involve music. There is archeological evidence in Europe of the use of musical instruments created with stone tools dating from at least 40,000 years ago (Higham et al. 2012). Music has also played an important role in the development of our ability to listen and communicate with each other. "Musical components are the fundamentals of communication . . . and rhythm, in particular, is the musical aspect of communication fundamental to the way in which we relate to ourselves and to others" (Aldridge 1989, 743).

The connections between music and science have been studied since the time of Pythagoras, and we can find relationships between music and mathematics, physics, and technology throughout our history. Music has also been used in healthcare as a therapeutic tool in stress and pain management, rehabilitation, and behavior modification. Recent studies in neuroscience show the effects of music on our emotions and physiology: exposure to various genres of music can affect changes in our breathing, heart rate, and the amount of stress hormones that our bodies release (Novotney 2013). The physiological effects of music can be measured and then used as an effective instrument in the healing professions and can contribute to the understanding of the human experience.

"The body of the speaker dances
in time with his speech.
Further, the body of the listener dances in rhythm
with that of the speaker!"
(Condon and Ogston 1966, 338)

Development and Context of the Course

After attending a workshop given by SENCER (Science Education for New Civic Engagements and Responsibilities), the authors sought to create a course that would foster the interdisciplinary connections between science and music. Due to the need for new general education courses and the university's emphasis on undergraduate research, we chose to develop a course that would fit into the existing undergraduate core curriculum. We received a SENCER Post-Institute Implementation Award and Auburn University funding to help with this project.

Auburn University is a land grant university with a student population of over 25,000 students. Students are required to take one three-hour course in the fine arts as part of the university's core curriculum. MUSI 2750 Music and Science was accepted by the University Curriculum Committee as a Fine Arts core course beginning Fall 2014. The first offering of the course in Fall 2014 included thirty-four students (70.6 percent male, 29.4 percent female), and Spring 2015 included thirty students (76.7 percent male, 23.3 percent female) for a total of 64 students, all taught by the authors. These students were traditional college-age students, the majority of whom were engineering and science majors, predominantly in their freshman and sophomore years. This was the first time that such a high percentage of STEM majors were attracted into a single core music course.

Course Objectives and Expected Outcomes

Course Description: This course explores the relationship between music and science in society from antiquity to the modern day. It is designed for non-music majors who have an interest in music and science. *(See table 1 for objectives and expected outcomes.)*

Course Design

The first offering of the course was primarily a lecture-based class. The class met once a week for two and a half hours. Each week, a new topic exploring the connection between music and science was discussed. Areas included music and its relationship to math, physics, technology, sociology, neuroscience, biology, and healthcare. In addition to the traditional course format (lectures, readings and discussion, quizzes, and final exam), students were expected to participate in two experiential learning

TABLE 1. Course Objectives

Course Objectives and Expected Outcomes: By the end of the semester, students should be able to:
1. Demonstrate an overall understanding of the relationship between music and the sciences throughout history.
2. Demonstrate an understanding of the scientific process as applied to a research project.
3. Demonstrate the ability to work as a team member on a project.
4. Demonstrate an understanding of basic music principles and their origins in society.
5. Demonstrate the ability to identify common elements of music and to use appropriate musical terminology in writing about music.
6. Demonstrate an understanding of the development and characteristics of musical instruments and compositional techniques as a result of advances in science and technology.
7. Demonstrate an understanding of the influence of society on music and related scientific advancements during the various historical periods.
8. Demonstrate an understanding of the effect of music and technology on cultural development.
9. Demonstrate an understanding of the process of listening to music and its effect on the listener.
10. Demonstrate an understanding of the creative process.
11. Demonstrate the ability to articulate aesthetic judgment regarding their listening experiences.

activities: concert attendance/report and a team-based research project/presentation. The concert experience occurred in both semesters, including the initial class offering, while the research project was added the second semester the class was taught.

Concert Experience

Students were expected to attend and report on a live concert. They were given guided-listening exercises during class to help prepare them for this assignment. In their report, they were expected to incorporate terms and concepts learned from the course, discuss the scientific and technological developments in society that affected the music and musicians, describe the listening experience using aesthetic judgment, and give an observation of the creative process in the concert.

Team-Based Undergraduate Research Project

Five teams of five or six students were formed to participate in the research project that measured the physiological effects of two contrasting selections of music on human subjects. Teams were constructed using theories on the creation of high-performance teams (Katzenbach and Smith 2006). Students were given guidelines on team building and how to make teams effective. They were given some class time in which to meet, but were also expected to meet outside of class. (This was factored in the time required for course assignments.) Each team was required to submit a team charter due during the sixth week of class. Guidelines were given for the research project with due dates for various stages of the project. The project report components included a title page, abstract, introduction and research question, description of methods/data collection, presentation of data, results, conclusion, future work that might come out of the project, and bibliography. (See grading rubric below.) The first half of the project was due during the ninth class meeting and feedback from both instructors was given. Data were collected with a BIOPAC system and analyzed using SPSS 22. The final report was due the last day of class, and teams presented their projects to the rest of the

TABLE 2. Course Schedule

COURSE SCHEDULE	
Week 1	The Origins of Music
Week 2	Music Elements and Terminology
Week 3	Pythagoras: Music, Mathematics, and the "Harmony of the Spheres"; Intro to team building
Week 4	Quiz 1; Guided Listening; Teams assigned
Week 5	Music and Mathematics; Discussion of team charter and research project
Week 6	Music and Physics; Team charter due
Week 7	Music and Technology; Discussion of essay assignment
Week 8	Quiz 2; Guided Listening; The Creative Process; Discussion of concert report assignment
Week 9	Music and Sociology; First half of research project due
Week 10	Music and Neuroscience
Week 11	Music and Neuroscience
Week 12	Quiz 3; Guided Listening
Week 13	Music and Healthcare; Essay assignment due
Week 14	Music and Biology: What Makes a Musician ?; Concert report due
Week 15	Research project report due; Team presentations
Finals	Final exam

class. Team members filled out an evaluation form on the work of each student in their own team and on the overall presentations of the other teams.

Preliminary Findings

COURSE GRADING COMPONENTS	
3 Quizzes (100 pts. each)	300 pts.
Team Charter	50 pts.
Research Project	275 pts.
Written Essay	100 pts.
Concert Report	100 pts.
Final Exam	175 pts.
Total	1000 pts.

RESEARCH PROJECT GRADING RUBRIC	
Abstract	20 pts.
Introduction/Background and Research Question	50 pts.
Methods/Data Collection	50 pts.
Presentation of Data and Results	50 pts.
Conclusion	25 pts.
Future Work	15 pts.
Group Presentation of Project	50 pts.
References	15 pts.
Total	275 pts.

To assess the impact of the course on academic gains, the students were given a SALG (Student Assessment of Their Learning Gains) pre-test survey at the start of the course and a post-test survey at the end of the course. Areas assessed by both pre- and post- SALG surveys included (1) student understanding of concepts explored in the class, (2) increase in skills as a result of work in class, (3) class impact on student attitudes, and (4) integration of learning. The responses to the survey were anonymous and did not affect the students' overall academic grades in the class.

Preliminary results of these surveys, comparing Fall 2014 (no research project) to Spring 2015 (research project added), showed gains in each of the areas listed above. Student comments on teaching evaluations indicated that students felt they improved their individual communication skills and ability to work in teams.

Future Directions

We will continue to offer the course with the undergraduate research project. An IRB application is in progress, as we plan to complete an in-depth analysis of the SALG survey assessments and also use the physiological results of the student projects for a study on how different types of music affect human physiology. We will be working with an honors student and have plans to publish the results and present them at a conference.

We have recently received outreach funding to add a civic engagement component to the course. In Spring 2016, student teams will share their knowledge of music and science with K-12 students. The teams will be given assignments to develop various activities for elementary students based on material learned in the Music and Science course. These activities will engage the elementary students with interactive learning, such as constructing simple musical instruments or listening/reacting to various kinds of music. The teams will document their experiences, get feedback from the elementary school students, and present reports to the rest of the Music and Science class at Auburn. A primary goal of the outreach project is to connect with future generations of students who may chose careers in fields involving STEM and the humanities.

Summary and Conclusion

We have successfully implemented a new general education course that integrates the disciplines of music and science. After initially offering it primarily as a lecture-based course, we added a team-based research component that engages the students in an active learning experience. We have evaluated the course using the SALG assessment tool and are in the process of applying for IRB approval so that we can publish the results of the students' work.

This course has helped us promote the relationship between science and the humanities with the understanding of the past and connections to today's world and the future. We appreciate the support of SENCER and Auburn University in this endeavor.

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PROJECT REPORT

Scientific Examination of Cultural Heritage Raises Awareness in Local Communities: The Case of the Newly Discovered Cycle of Mural Paintings in the Crucifix Chapel (Italy)

Antonino Cosentino
Cultural Heritage Science Open Source

Abstract
The preservation and conservation of cultural heritage material is matter of increasing civic importance, particularly in communities where public resources are scarce. Although this issue is generally considered a challenge for the humanities, scientific research also plays an invaluable and unique role in promoting and preserving cultural heritage in local communities. Because of recent advances in technology and methods of scientific analysis, a deeper understanding of fine art works can be achieved than was ever possible by a simple visual examination. Questions that were once difficult to answer, including precise materials and techniques or original and restored areas, can now be clarified through relatively straightforward scientific experiments using accessible technology. This development opens a new and fruitful avenue for enriching science education, in both formal and informal contexts, through the lens of a pressing civic issue: the investigation and preservation of endangered aspects of local history and culture.

This paper describes the scientific studies carried out on a cycle of 18th-century wall paintings discovered in 2012 in a small Italian village. An international team of research institutes (USA, Denmark, Portugal, and Italy) were involved in the technical examination of the cycle. The scientific findings, which were presented to the local community during a public conference, raised awareness of the value and significance of their unique cultural assets. This represents a successful model for civically engaged science that can bring international expertise to bear on a specific challenge to a local community.

Civically Engaged Science to Preserve Local Art and Archaeology
The preservation of cultural heritage is a critical civic responsibility, especially in Italy where the vast array of cultural treasures ranges from the renowned mega-cities of Rome, Florence, and Venice to almost every village. This rich distribution of material culture demands local civic

engagement simply because national and governmental institutions alone cannot effectively manage the sheer quantity and scope of artistic and archaeologic heritage sites. Consequently, the role played by local advocates and organizations is critical, though not always obvious to communities faced with other pressing needs. Advocacy and public education is needed to shed light on the connection between civic and economic wellbeing and the preservation and protection of cultural heritage (Bonacini et al. 2014). In Italy, as well as in other European countries, there have been significant cuts to public funding for art conservation. It is therefore more urgent than ever that local communities mobilize and provide adequate financing to appropriately conserve and maintain their cultural heritage.

Cultural Heritage Science (CHS) is a discipline that examines works of art and archaeology by means of technical and scientific methodologies. Information derived from these studies is used to understand not only when these artifacts were made, who made them, and how they were made but also, more importantly, how are they to be preserved, and what conservation treatment represents the best option and why. As a scientific practice CHS must draw on a wide range of disciplines and fields beyond the sciences, including history, art history, archeology, ethics, public policy, and law. This article outlines a project in Italy to promote the conservation of a cycle of early 18-century mural paintings. It discloses the role of Cultural Heritage Science in raising community awareness of material culture as a civic asset, as well as awareness of the importance of science and technology to the preservation of cultural heritage.

Innovative, Affordable and Sustainable Scientific Methods

Scientific examination and documentation of art is notoriously expensive. The most important and recognizable works of art are subjected to extensive scientific examination by highly trained experts, using state-of-the-art equipment that costs millions of dollars. This is clearly an impossible goal for the conservation and preservation of the vast majority of cultural heritage objects, which may not be rare or distinguished by global standards but are nonetheless critical to the identity and history of local communities, most of which lack the financial and technical resources of major capitals and their world-class museums. These large museums house "priceless" collections and maintain conservation departments equipped with cutting-edge technologies. In contrast, small to medium-sized cultural institutions have relatively limited access to advanced science and technology and conservation expertise.

Cultural Heritage Science Open Source (CHSOS) was launched in 2012 to bridge this technological divide, to develop and disseminate affordable and sustainable methodologies for art examination that can reach a much larger constituency of local cultural institutions This search for low-cost art examination and documentation is a rapidly expanding research topic, and a growing number of scholars are exploring affordable technical solutions for historical architecture documentation (Santagati et al. 2013). CHSOS disseminates methods for art examination in three significant ways, focusing specifically on low-cost technical solutions: through its popular blog, through publications in open access peer reviewed journals, and through training programs. The CHSOS blog has attracted a growing network of art conservation professionals interested in introducing Cultural Heritage Science concepts into their work. The blog has also inspired collaborative field projects with local stakeholders, such as the Catacombs in Syracuse (Cosentino et al. 2015; Stout et al. 2014) and the Sicilian carts museum (Cosentino and Stout 2014).

The Crucifix Chapel

A cycle of 18-century mural paintings was revealed in 2012 during maintenance work in the Crucifix Chapel of the Mother Church in Aci Sant'Antonio, Italy. The paintings have survived along the corners of the originally square chapel that was later altered, acquiring the current octagonal-shaped construction. All of the murals except the scenes on the corners have been destroyed and irretrievably lost (Figure 1).

CHSOS Studio is located in Aci Sant'Antonio. This discovery in the local chapel was selected as a pilot study to determine whether scientific research can promote better care of cultural heritage, even when financial resources are limited and the heritage material is of local,

FIGURE 1. (A) Crucifix Chapel, Mother Church, Aci Sant'Antonio (Sicily). Photo of the chapel from the transept after the renovation. The frescoes are visible through the windows on the walls facing the four corners. (B) Left border of the third scene, Agony in the garden. The original plaster was taken down in order to anchor the new wall. (C) Floor plan with the description of the remaining scenes. (D) Split panorama of the chapel

rather than regional or national, significance. From the moment of their discovery it was clear that the newly discovered murals were in critical need of conservation treatment. CHSOS advertised and solicited the international academic community for help in performing an accurate scientific assessment of the murals, which ultimately resulted in a well documented, informed conservation treatment strategy. The mural paintings were first documented in 2013 by CHSOS using technical photography (TP) (visible, raking light, infrared, ultraviolet fluorescence, and infrared false color).

TP represents a collection of broadband spectral images realized with a modified full spectrum digital camera and using different lighting sources and filters to acquire images useful for art diagnostics. TP imaging methods are non-destructive, fast, and use relatively inexpensive equipment and tools. CHSOS donated the time needed to perform the initial examination. The results served as a catalyst that gained the cooperation of three universities. A doctoral candidate at University of California San Diego (USA), Samantha Stout, provided on-site analytical pigment studies, which used a portable XRF spectroscopy system; analysis of paint fragments were provided by researcher Milene Gil from the Hercules laboratory at the University of Evora (Portugal), using optical microscopy, scanning electronic microscopy with x-ray spectrometry (SEM-EDS), X-ray diffraction (XRD) and µFT-IR; and finally, Terahertz examination of the plaster work was performed by Danish Technical University (Denmark) doctoral student Corinna Koch Dandolo.

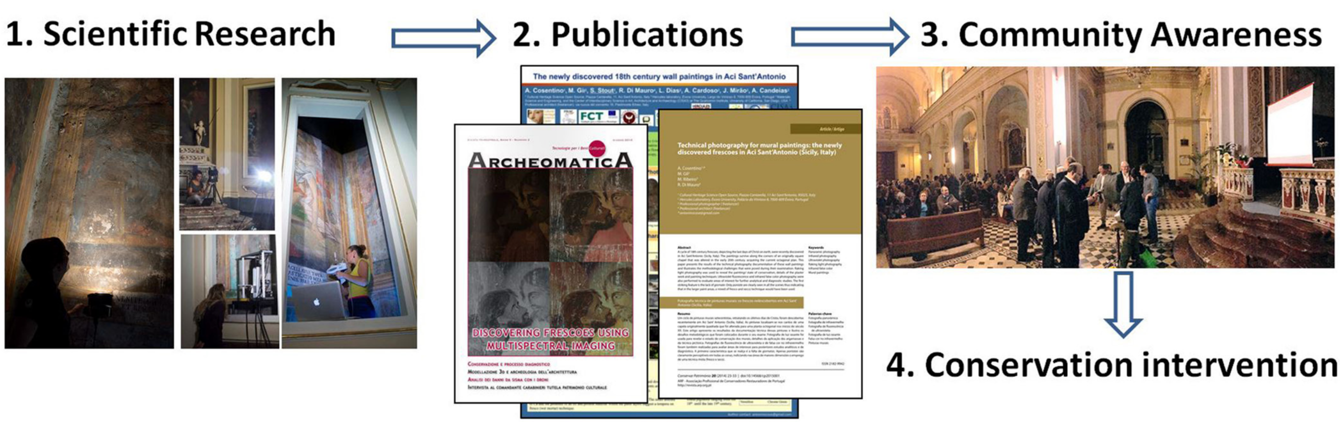

FIGURE 2. Scientific research can promote community awareness and lead to better care of local art and archaeology.

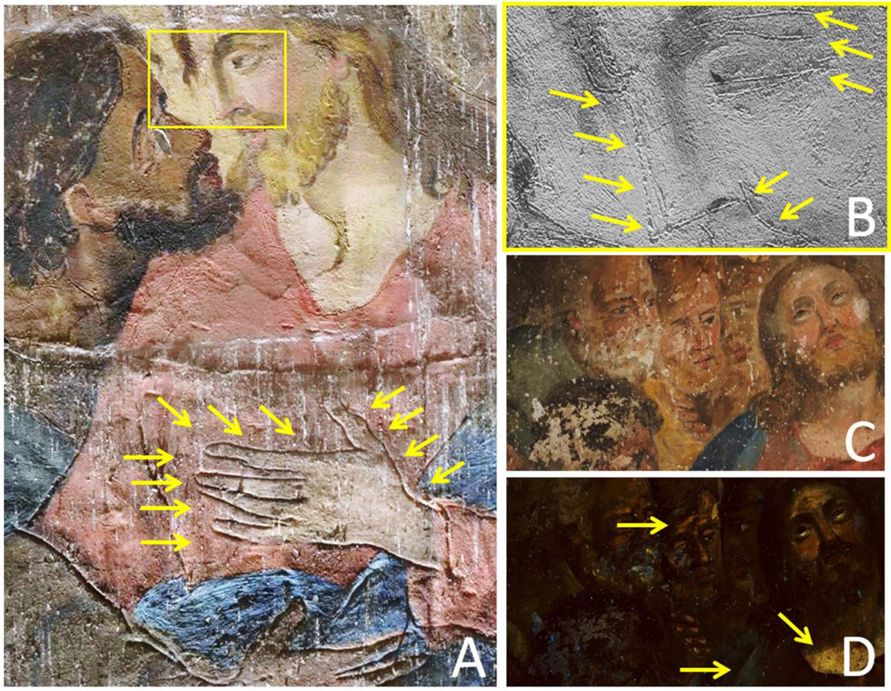

FIGURE 3. Crucifix Chapel, Mother Church, Aci Sant'Antonio (Italy). (A) Raking photo reveals deep incised lines for the hands of Jesus and Judas, suggesting that they were made by the pressure of a pointed tool through a cartoon. (B) Raking photography in the infrared increases the reading of the shallow incisions made with a pointed tool for the faces. (C) Photo of the Last Supper scene. (D) The ultraviolet fluorescence photo reveals an a secco application of the paint using an organic binder, which fluoresces under UV light.

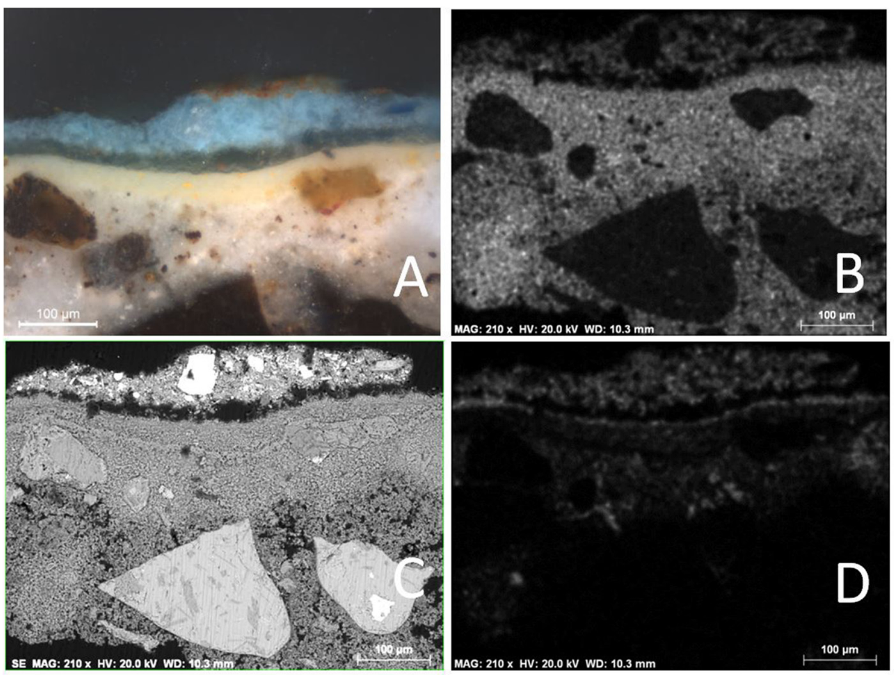

FIGURE 4. (A) Cross section, optical microscope. FT-IR spectroscopy showed that the paint was applied with a protein binder. (B) The a secco method is also suggested by the calcium mapping image, which shows that the pigment was not mixed with the wet plaster. (C) The SEM image of the sample suggests that the mortar was partially or completely dry when the following layers were applied. A thin layer of calcium carbonate precipitation can be observed. (D) The sulfur mapping image shows that a layer of gypsum mixed with yellow ochre was then apparently laid as a ground layer.

This international collaboration has resulted in peer-reviewed publications (Cosentino et al. 2014a; Cosentino et al. 2014b). The data were subsequently used to formulate a conservation intervention strategy that was presented in 2015 to the community of Aci Sant'Antonio at a conference where the project collaborators reported their findings.

Participants greatly benefited from all aspects of this unique research endeavor. International graduate students and scholars were drawn to Italy because of the abundance of cultural heritage objects and locations, which represent a unique opportunity to test their technical methodologies and learn first-hand about traditional western historical art materials. In turn, members of the local community benefited from their expertise and were informed of the significant artistic features present within the discovered cycle. The scientific research effectively engaged the local community, and the conference helped raise funds for the eventual cleaning and conservation of the paintings. This project, then, represents a successful model of the public

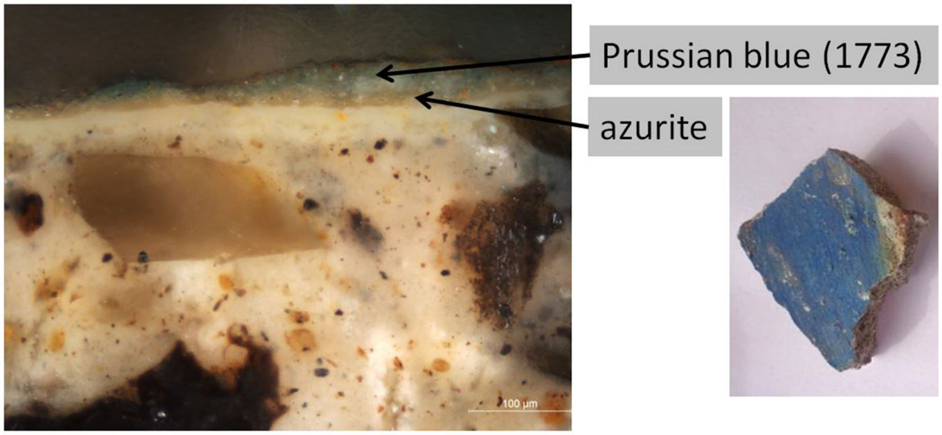

FIGURE 5. Cross section examination of the fragments shows that the scenes were repainted with modern pigments, such as Prussian blue (manufactured from 1773) over older azurite.

communication of science: the active process of scientific inquiry raised local community awareness and appreciation to a level that generated the financial support that was needed to professionally treat and preserve the art object (figure 2).

The local community setting encouraged an explanation of the findings that was straightforward and avoided unnecessary technical jargon. More significantly, in this scientific investigation context, it was TP (technical photography) that led the way. TP proved to be the most cost effective of the methods used and is capable of providing a great deal of information on the painting technique (figure 3). TP is also the most appealing for a non-specialized audience, as the images convey the findings more easily.

The analysis of seven plaster wall fragments revealed that an a secco technique (use of an organic binder rather than the fresco method) was used for the wall paintings (figure 4). The analysis also revealed large areas of repainting using modern pigments applied directly over the original paint layer (figure 5).

Conclusions and Implications for Science Education

Scientific research on the newly discovered wall painting cycle in Aci Sant'Antonio (Italy) illustrates that cultural heritage science methodologies can be used successfully to promote the conservation of art and archaeology, even in poorly funded local communities. The initial findings, detailed visually through technical photography coupled with portable and benchtop spectroscopic methods, proved a successful means to raise awareness of the relevance of science to the community's identity and history, and to the preservation needs of its specific cultural heritage material. The ability of modern scientific methods to provide evidence and increase public knowledge provided the political and financial leverage needed to take action.

Appropriately, the public conference was held in the same church where the mural paintings are located. Here in this setting the local community participated in an integrated learning experience that spanned both science and humanities, providing information about the painting technique and materials used by the original painter and by the others who, centuries later, retouched the paintings. In this specific case the research for this project was achieved without a direct financial contribution from the community. Indeed, the case study was such a compelling educational opportunity that three major foreign universities donated financial resources and provided Ph.D. students to perform the examination. All participants benefited. The conservation scientists worked together as an international team, comparing notes on the data they obtained with complementary equipment. Today the local community better understands the importance of their newly discovered cultural treasure and is justifiably more proud of it. And the results have proven contagious. Soon after the papers were published, CHSOS was contacted by the community of another village in Sicily, which had followed the Crucifix Chapel studies and now desired to replicate the same model to promote the conservation of mural paintings in one of their medieval churches.

The next step for CHSOS will be to integrate the formal and informal learning environments by extending the academic participation in this initiative through a summer school program for undergraduate students. This project, which will teach rigorous science content "through" the civic challenge of preserving local cultural heritage, will be offered to U.S. college students who are interested in integrating the study of science with art history, archeology, and material culture studies. It will be based on the training programs that CHSOS has offered to professionals and graduate students, and it will be fully hands-on, bringing students to work on selected field projects that conserve Italian art and archaeology while engaging communities in the preservation of their cultural heritage.

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About the Author

Dr. Antonino Cosentino founded CHSOS in 2012. Before directing CHSOS he taught "Scientific Methods for Art Investigation" in Italy and at the Pratt Institute in New York and carried out scientific examinations of important works of art as a researcher for European and American institutions such as the European Mobile Laboratory for Art investigation (MOLAB), the New York's Metropolitan Museum of Art (A.W. Mellon Fellow in Conservation Science) and the University of California San Diego.

PROJECT REPORT

Storm Impacts Research: Using SENCER-Model Courses to Address Policy

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Abstract

Hurricane Irene and Superstorm Sandy caused severe damage to the Connecticut shoreline in 2011 and 2012 respectively. The close temporal succession of the two storms has intensified concerns about rising sea levels and storm intensification attributable to climate change. In response, students at Southern Connecticut State University who have taken a SENCER model course, "Science and the Connecticut Coast," as well as students from similarly constructed courses that teach environmental science "through" issues of civic consequence, are conducting research on coastal vulnerability with the goal of impacting policy recommendations that could increase the state's coastal resilience in the face of future storms. The results of these studies suggest that the presence of a wide buffering beach was the most common factor in reducing storm wave damage, and that the characteristics of the storm surge inundation pattern were unexpected. Among the recommendations stemming from this research are that management of beach sand become a priority for the state, that management of beach sand be prioritized according to locality and benefit, that the state provide a mechanism for towns to reclaim eroded beach sands that provide a buffer to storm waves, and, finally, that coastal emergency plans include accurate storm tide inundation maps that are accessible to the public.

Introduction

According to the National Council Population Report (NOAA 2013), the Connecticut shoreline has the fifth highest (non-freshwater) coastal population density in the United States and is one of the most intensively developed shorelines in the country. The ratio of the value of total insured coastal county property/km of linear shoreline length for Connecticut is $3.69 billion/km, second only to New York State (AIRWorldwide 2013). In the face of climate change and sea level rise, shoreline properties in Connecticut face increased risk of damage caused by hurricanes and other large storms. This is due in part to poorly informed policies that fail to recognize the regional beach dynamics of Connecticut's formerly glaciated, fetch-limited shoreline (Tait and Ferrand 2014).

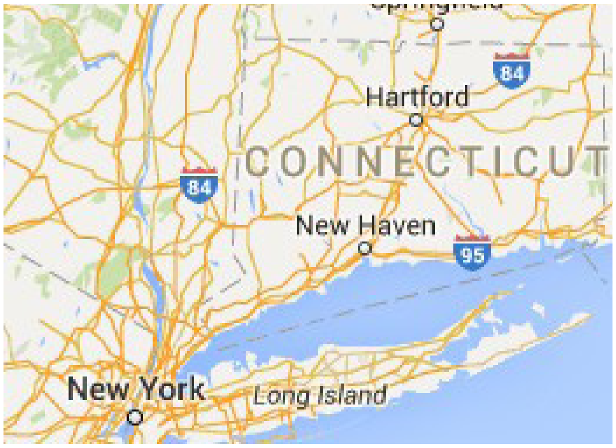

FIGURE 1. Long Island and Connecticut. *(Figure courtesy of Google Maps.)*

In particular, along many parts of the Connecticut shore, communities depend on the presence of sandy beaches to shelter coastal structures and infrastructure from storm damage. While the shoreline is periodically exposed periodically to erosive storm waves, the moderately large, long period swells that rebuild beaches are typically absent due to the sheltering effect of Long Island (Figure 1). As a result, Connecticut's beaches are chronically erosive.

By connecting students with a multifaceted understanding of Connecticut shorelines and providing hands-on experience with storm damage, the class becomes a site of learning, both inside and outside the university walls. From statistics and coastal processes, to teamwork and presentation skills, SENCER courses in what is now the Department of the Environment, Geography and Marine Sciences at Southern Connecticut State University have become a departure point for students to both conduct coastal research and apply that research to coastal policy analysis.[1] After learning important concepts and field and laboratory techniques in formal courses, highly motivated students go on to conduct research as fellows of the Werth Center for Coastal and Marine Studies. It is interesting to note that the students involved in this research are not necessarily science majors but have developed an interest in science as a result of their experiences in these interdisciplinary science courses. Two such courses, "Science and the Connecticut Coast" and "Coastal Processes and Environments," allow students to experience and understand various coastal environments, their origins, and the processes that shape them, as well as associated environmental issues. Although the focus of this article is research on storm impacts, department coursework and research at the Werth Center also focus on water quality monitoring and coastal sediment pollution by heavy metals.

Hurricane Sandy moved up the Atlantic coast in late October 2012, interacting with a strong short-wave, mid-latitude cyclone along the way. The combined storms created an extremely large and very low-pressure superstorm with intense winds on the northern side of the cyclone (Grumm and Evanego 2012). These winds, with attendant surge and storm waves, hit the coastal town of East Haven, Connecticut on October 29, 2012. The impacts of Sandy are convolved with those of Hurricane Irene, which had devastated the area just one year earlier in August 2011. While people were still recovering from Irene, Sandy intensified and and spatially extended the damages that already existed. In records of storm damage maintained by the town, specific damages were sometimes not even attributed to a particular storm, a clear indication of the overlapping impact of the two storms (Tait and Ferrand 2014). Superstorm Sandy was generally classified as more intense in terms of maximum storm surge, maximum wind speeds, diameter, and barometric pressure (Fischetti 2012). Prevailing conditions in Connecticut, however, served to moderate the storm's impact relative to Irene. The storm's direction shifted west, sending the eye into New Jersey, so that winds along the Connecticut shoreline blew alongshore rather than onshore, which reduced the magnitude of the surge in the East Haven area. Sandy's forward speed accelerated from approximately 15 mph to 29 mph, so that the storm arrived in the East Haven area earlier than it would have otherwise. According to records from the NOAA New Haven CT tide gauge, Sandy arrived in East Haven at 8:06 p.m., just two hours

1 Southern Connecticut State University (SCSU) has developed three courses that have been selected as SENCER Models: "Computer Ethics", 2006; "Science on the Connecticut Coast", 2007; Pollinators: A Case Study of Systems Thinking and Sustainability", 2014. Since 2004, thirty-two faculty members from SCSU, encompassing twelve departments and three of its schools, have attended Summer Institutes, incorporated SENCER ideals into existing courses and programs, and created new courses. For this work, SCSU received the 2015 William Bennett Team Award for Extraordinary Contributions to Citizen Science from the National Center for Science and Civic Engagement.

FIGURE 2. Cosey Beach. *(Photo courtesy of the Connecticut Department of Energy & Environmental Protection.)*

after a spring low tide, resulting in a storm tide of 8.9 ft (2.7 m) relative to mean sea level, just 7.9 in (20 cm) higher than Irene. If not for these factors, the storm surge would have been higher and would have occurred nearer to a spring high tide, as was previously anticipated. Nevertheless, storm surge inundation, high winds and storm waves caused considerable damage (Figure 2).

To better understand the risk posed to structures and infrastructure, students who had gained research experience in SENCER courses investigated the various controls on wave damage and patterns of inundation in order to assess vulnerability to future storms. The shoreline characteristics investigated with respect to wave impacts included the elevations of houses and roads, beach width and beach erosion patterns, the presence or absence of sea walls, and the amount and types of damage sustained. Spatial patterns of inundation were examined using flood debris deposits, Light Detection and Ranging (LIDAR) data, and Geographic Information Systems (GIS) mapping technology.

Research Activities

Methodology for these studies involved quantitative field observations followed by quantitative laboratory and geospatial analysis. Students were prepared by their classroom experiences to conduct rigorous fieldwork, gather reliable data, analyze the data carefully, and make reasonable interpretations. Collectively, the data constitute a detailed look at various characteristics of the East Haven coastline that contribute to the town's vulnerability to wave damage and to inundation during large storms. Research activities included construction of coastal road elevation maps, measuring beach profiles and erosion patterns, a house-by-house wave damage assessment, and an inundation map series that included the actual inundation pattern and patterns for other potential scenarios. It should be noted that the research performed by the students has been used in the town of East Haven's report to FEMA and will be used by the Town Engineering office for future risk assessment.

Wave Damages

Coastal road elevation maps

A series of road elevation maps were generated. Students used a CST/Berger 300-R total station to gather elevation data. The total station uses a modulated infrared laser beam and prism reflector to obtain highly accurate XYZ coordinates, which must then be assigned a coordinate system that includes a known elevation. Previously existing town engineering benchmarks served as points of known elevation. The locations of surveyed elevation points were recorded using geographic positioning technology (GPS) approximately every twenty feet or at every noticeable change in road elevation, whichever came first, in the centermost part of the road. Data were then visualized using ArcGIS by importing point locations and displaying them as XY point values. Spot elevations were then manually input into a new corresponding float point field. Elevation rasters of the same width as the roads were then created using spline and inverse distance weighting interpolation.

Beach profiles and erosion measures

Students also collected data on beach erosion (or stability) by measuring the difference in beach profiles over time. Profiles were measured and re-measured at fixed geographic locations. Over the past 3.5 years, beach profiles were measured along East Haven beaches to better understand longer-term erosion or accretion patterns. Where possible, profile measurements were spaced along the beach approximately 200 m apart. Profile locations were recorded and measured from the seaward-most edge of coastal structures, or from the edge of the beach, to maximum wading depth. These measurements were then plotted using Microsoft Excel to reveal spatial patterns of erosion over time. Calculated variables included the width of the beach to the mean higher high water (MHHW) intercept and the volume of beach sand under the profile and above the mean lower low water elevation. Volumetric measurements were given units of m3 per unit length of shoreline. This allowed total volume of sand calculations for specified reaches of beach.

Structural damage assessment

In addition to empirical quantitative research, one student conducted door-to-door interviews at each house along the East Haven coastline to determine the nature of wave damage to each structure. A set of questions was asked at each home including the cost of structural damage that occurred, what type of damages occurred, whether or not a sea wall was present, and whether or not the structures were raised at the time. A map was creating using Google Earth to show the structural damages pattern. Structures were put into one of the following categories: severe damages requiring demolition, severe damages, moderate damages, minor damages, and no damages.

Inundation

Inundation map series

Immediately following the flooding that accompanied the storm surge of Superstorm Sandy, debris lines in the town of East Haven associated with the peak storm surge were located and photographed, and addresses were noted. Blue dots were spray painted to represent the upper boundaries of the debris line. These point locations were then recorded using GPS and their elevations were measured using laser-based surveying technology (total station) (Figure 3). An average elevation for the flood line point locations was then calculated along with a measure of variability (standard deviation). The average elevation for the flood debris was then compared with the peak storm surge water elevation measured at the nearby (~ 4 km) New Haven, CT tide gauge. The difference between the tide gauge elevation and the elevation determined by averaging debris elevations was just 1.5 cm, allowing a high level of confidence in the data collected.

Flood line locations and elevations were then visualized using Geographic Information Systems (GIS), resulting in a series of maps: (1) storm surge inundation of Superstorm Sandy, (2) storm surge inundation of Superstorm Sandy had it come at high tide instead of a couple of hours after low tide, and (3) storm surge inundation projections based on IPCC (2014) estimated sea level rise. This map series was created in ArcGIS utilizing high-resolution LIDAR imagery and 2010 USGS orthophotography. LIDAR imagery elevation information was extracted and displayed using a semi-transparent teal blue color to signify all areas that had been inundated during Superstorm Sandy (elevations at or below 8.9 ft (2.7 m)). A second semi-transparent layer displayed with purple color was added to signify the hypothetical Sandy at high tide storm tide elevation (elevations from 8.9 ft (2.7m) to 12 ft (3.7m)), as was originally predicted. Representation of these two scenarios were then overlain on USGS orthophotography. All remaining elevations were given

FIGURE 3. Data collection using laser-based surveying technology. *(Photo courtesy of Isabel Chenowet.)*

FIGURE 4. Cosey Beach during Hurricane Irene. Note collapsing house on left and wave splash overtopping house in center. *(Photo courtesy of James Tait.)*

FIGURE 5. A coastal road elevation map. *(Figure courtesy of Michelle Ritchie.)*

no color to signify locations free from inundation. Flood debris point locations were then added and displayed as XY point values. These values matched up exceedingly well with the upper boundaries of the storm tide inundation determined from the LIDAR data.

Results

Wave Damages

While the presence of seawalls and raised structures all influenced the degree of wave damage, they were not the primary determinants. For structures that were raised, elevation on pilings often proved effective. However, in some cases, the magnitude of elevation was insufficient relative to peak surge elevation. In other cases, minor damages occurred to fences or stairs to elevated decks. In general, however, few structures were elevated before Sandy. Seawalls were frequently overtopped, deflected energy onto adjacent structures, or increased the elevation of wave splash (Figure 4). When the coastal road elevation maps (Figure 5), the damage assessment map (Figure 6), and beach profile measurements (Figure 7) were compared, it became apparent that beach dimensions and road elevation played the largest role in determining the severity of wave damage. In particular, older cottages which were not elevated and lacked structural robustness sustained only minor damages if they were sufficiently far back on the beach profile, i.e., had a broad protective beach. This was the case even if road elevation was relatively low. In other areas, road elevation played a key role. The central

FIGURE 6. Damage assessment map. *(Figure courtesy of Stephanie Cherry.)*

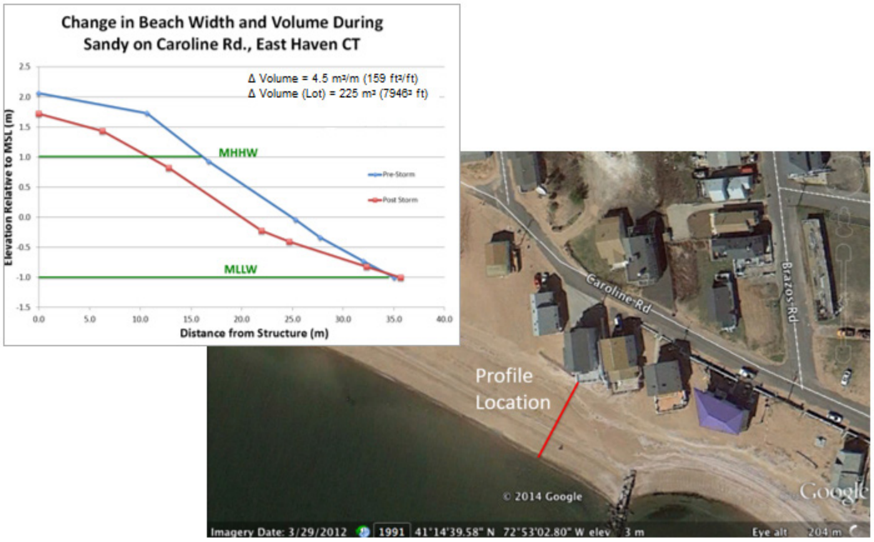

FIGURE 7. Changes in beach profile via volume of sand. *(Figure courtesy of James Tait.)*

FIGURE 8. Map of Superstorm Sandy. *(Figure courtesy of Michelle Ritchie.)*

portion of Cosey Beach Avenue, for example, is the highest part of the road topographically. Damages here were minor to non-existent. In the western portion of Cosey Beach Avenue, houses were the most robustly built, typically had low seawalls, but were at a lower road elevation than those in the central portion, and more importantly, had no buffering beach at high tide (compare Figures 5 and 6).

Inundation

Inundation, while less dramatic than wave damage, also caused considerable damage and collectively may have been more costly. Sandy's peak storm tide in East Haven was 8.9 feet (2.7 m). Mean higher high water in this area is 3.4 feet (1.0 m). On the morning of October 29, Sandy shifted its track westward toward New Jersey and accelerated to nearly twice its forward speed. As a result, the peak surge arrived in the East Haven (New Haven) area just after low tide. Using NOAA water level data for the New Haven station, the storm tide (predicted tide +the storm surge) elevation for the area was calculated and mapped (Figure 8). The storm tide for Sandy arriving at high tide was 12 ft (3.7 m). The areal extent of flooding and the depth of inundation would have been considerably worse. In addition, escape routes that functioned under the actual storm tide elevation might not have been accessible had Sandy's forward speed not changed. The difference between the actual storm tide and the potential storm tide is similar to the rise in sea level (~ 3 feet). predicted for the end of the century by some climate models. The pathway of flooding was also an issue. In many places along the East Haven coast, salt marshes back areas of housing and other development. In most cases, flood waters moved landward from the marshes in addition to overtopping the beaches. As a result, distance from the shoreline was not a guarantee of safety. In one area, the flooding extended the shoreline of Long Island Sound ~1845 feet (~562 m) landward via marsh flooding.

Policy Discussion

In keeping with the ideals of SENCER courses, this student-driven research has substantially increased the fund of public knowledge of storm impact on the Connecticut coast and provided critical information on which to ground public policy. Now more than ever, students, the general public, and politicians alike have come to realize that climate change is significantly impacting our lives. This is especially measurable in areas like the town of East Haven that were severely impacted by Hurricane Irene and Superstorm Sandy in recent years. In fact, following Hurricane Irene the Connecticut State Legislature authorized the Shoreline Preservation Task Force, a bipartisan group that has made policy recommendations and called for the integration of climate change and sea level rise science into both resource development planning and municipal zoning regulations (Tait and Ferrand 2014).

When assessing coastal vulnerability, it is essential that we look closely at the characteristics of an area to understand how they combine to constitute that area's vulnerability. In the case of East Haven, Connecticut, topographic elevation and the presence of seawalls and raised structures all play roles in determining the severity of wave damage. Data analysis, however, indicates that beach width and height were the primary determinants of the degree of wave damage to coastal structures during Irene and Sandy. With this information, locally proposed policy changes can be made to more easily and economically maintain the buffering capacity of beaches in the face of future storm waves and improve the accuracy of evacuation warnings.

For example, direct development of the shoreline should be strongly discouraged. The long-standing assumptions that the Long Island protects the Connecticut coast, or that erosion is random rather than methodical, need to be dispelled. In addition, a managed retreat from the coastline in areas of high vulnerability needs to become part of policy conversations (Tait and Ferrand 2014). Furthermore, less expensive alternatives to current beach nourishment projects, which consist of trucking in sand from other regions, should be explored. One such economical option would be to pull eroded sands back onshore. In general, *regional* planning to make coastal communities more sustainable in the face of future storms needs to be undertaken. Although the State of Connecticut has established an interdisciplinary research, outreach and education center (Connecticut Institute for Resilience and Climate Adaptation) that offers support to local communities, response to Irene and Sandy still largely resides with individual communities.

One improvement to the current system might be a regional sand management plan. At present, beach restoration is discouraged and when replenishment does occur, sand is typically trucked in or shipped in from distant offshore borrow areas or regional quarries. Sand that was originally eroded from the beaches, however, typically accumulates just offshore. Using this sand source to replenish the most vulnerable beach areas according to a system of prioritization would be a significant improvement to the current system. In other areas, where replenishment is cost-prohibitive, prioritizing which assets to protect (i.e., which beaches to replenish), and which beaches should be surrendered to nature, would be another viable and more sensible option.

The results of these studies have been made available to the Engineering Department of the town of East Haven and to the Public Works Department of the town of West Haven to aid in their long-range and emergency planning efforts. Similar work is being done for the State Beach at Hammonasset. Recommendations based on the results of this work will be offered to the State Department of Energy and Environmental Protection as well as to the Environment Committee of the State Legislature.

About the Authors

Michelle Ritchie recently graduated with honors from Southern Connecticut State University with a Bachelor of Arts in Geography and a concentration in Environmental Studies. While at SCSU, she worked as a research assistant at the Werth Center for Coastal and Marine Studies and as an intern at the Office of Sustainability and Recycling Center. She is currently attending Binghamton University in pursuit of a Master of Arts in Geography specializing in Environmental and Resource Management while working as a graduate research assistant at the Hazards and Climate Impacts Research Center. Her research primarily focuses on hazard mitigation, planning and recovery.

James Tait is a professor of marine and environmental sciences in the Department of the Environment, Geography and Marine Sciences at Southern Connecticut State University. He received his Ph.D. from the University of California at Santa Cruz in Earth Science with a specialization in Oceanography and, in particular, Coastal Processes. Since 2011, his research has focused on the coastal impacts of large storms, including Irene and Sandy. Dr. Tait is a SENCER leadership fellow and a co-recipient of the William Bennett Team Award for Outstanding Contributions to Citizen Science. Along with his colleague, Dr. Vincent Breslin, he co-authored a course for the SCSU Honors College on Science and the Connecticut Coast. The course has students conduct scientific studies of storm impacts and coastal pollution in Connecticut. The course became a SENCER Model Course in 2007. Dr. Tait is also co-founder of the Werth Center for Coastal and Marine Studies at SCSU. The Center employs talented students as research assistants working on problems such as coastal vulnerability and resilience, metal pollution of coastal sediments and organisms, microplastics in the marine environment, coastal water quality changes, and response of corals to climate change in Long Island Sound.

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PROJECT REPORT

Teaching Through Human-Driven Extinctions and Climate Change:
Adding Civic Engagement to an Introductory Geology Course for Non-Majors

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Abstract

Two of the greatest challenges facing humanity—climate change and the dramatic loss of biodiversity—are best understood through the lens of deep time. We applied SENCER principles to redevelop an introductory paleontology course at the University of Kansas (Geology 121, "Life through Time: DNA to Dinosaurs") to help general education students understand the value of our discipline in the modern world. Our process included reducing content coverage and connecting geologic concepts to modern challenges, placing students in teams and implementing active learning in every class, and including a final research project that challenged students to mitigate the current mass extinction event. While students were initially uncertain about the new course since it would require more work on their part, final student comments on the class were overwhelmingly positive, and final grades improved dramatically over past semesters, despite a significant increase in the rigor of the course overall.

Introduction

Many students enroll in introductory geology classes merely to fulfill a distribution requirement (Gilbert et al. 2012). At the University of Kansas, all undergraduate students are required to take a natural science course regardless of their major, and this class is often their only college-level science class and the last science class they will ever take. Given that two of the most pressing issues facing humanity right now—climate change and the prospect of human-caused mass extinctions—can best be understood through a geological lens, we decided to redevelop Geol 121, "Prehistoric Life from DNA to Dinosaurs," an introductory paleontology class for non-majors, according to the SENCER model. Although geology majors can take this class to supplement the required introductory geology course, the majority of the students are not majoring in a STEM field.

Traditionally, this course has been lecture-based, and student learning was gauged by measuring the student's ability to memorize details about when various animals originated and went extinct through geological time. During the redesign process, we established two primary goals to guide our efforts: (1) geological and paleontological information would be interwoven with the interconnected civic issues of human-driven extinctions and climate change, and (2) students would actively explore and discover knowledge themselves, rather than passively receiving it. By teaching through these complex, controversial, and current issues, and by challenging students to directly engage with the science, we sought to increase student understanding of the scientific method and its impact on their everyday lives. This paper describes the redesign process and preliminary outcomes.

Methods

The redesigned class was offered in Fall 2014 to 60 students. This was the fifth time Olcott Marshall had offered this class, having taught the old version four times between Spring 2009and Spring 2013, to a total of 452 students. Olcott Marshall began the redesign process in March of 2014, and was guided and assisted from that time until the end of the semester by Bitting, whose role in the department was as a teaching specialist. To transform the class, three steps were necessary: (1) streamlining the material, (2) creating opportunities for active engagement, and (3) implementing a final project that allowed students not only to synthesize and evaluate all of the information they had explored during the semester, but to apply that information to matters of immediate societal importance.

Streamlining Material

The first modification was decreasing the amount of material the course would cover. The original version of the class covered 3.5 billion years of Earth history, with each day of the class dedicated to lecturing about a different period of geological time. This much material was overwhelming to the students and did not allow more than a superficial introduction. For the new course, we implemented a backwards design approach (Wiggins and McTighe 1998): First, we established two specific student learning outcomes related to human-driven extinctions and climate change: "Students will be able to

- analyze the extinction pressures acting on modern organisms in the context of those organisms' geologic, evolutionary, and climatic history.
- construct an action plan for mitigating the current mass extinction event that is informed by their understanding of organisms' roles in and relationships with the Earth system."

Based on these intended outcomes, we determined what content material to cover in class and shifted the emphasis of the course from declarative to procedural knowledge to allow students to practice skills that would allow them to succeed in the complex tasks leading to the outcomes above. The material we identified for the redesigned course had previously been covered in only eight lectures, but now the students would explore the material in-depth over the course of 30 class meetings.

Active Engagement

In previous years, students were mostly passive recipients of knowledge in the class and were expected to study facts, dates, and terms on their own to prepare for exams. In 2009, 2011, and 2012, student grades were determined solely by four exams. In 2013, students did a short five- to ten-minute activity at the end of each lecture, but these were done individually, and since the students left when they were finished, there were few opportunities for the class to summarize, debrief, or reflect on what they were doing or why.

For the redesigned class, we wanted students to engage with the material from the very beginning, to recognize that their learning occurred through actively exploring the information, and to apply, analyze, and evaluate their newfound scientific knowledge continuously. Every class period, the students worked through a series of two or three related activities designed to scaffold them through the process of activating and building upon prior knowledge (Linn 1995; Vygotsky 1980). Some activities required students to summarize and explain the conclusions of figures from published paleontological studies, while at other times the students worked with raw data they downloaded from the Paleobiology Database (http://paleodb.org) to interpret, examine, and craft hypotheses. To leverage students' social goals (Ford 1992), and to harness the power of peer instruction (Johnson et al. 1991), some of the activities were done in groups of three or four, and others required the students to work individually before consulting with their groups (think-pair-share) (Table 1). By including a wide range of types of activities, we were able to provide instructional conditions that appealed to extroverted learners, such as

TABLE 1. Types of Activities Introduced in Transformed Class

IN-CLASS ACTIVITY TYPE		ADDITIONAL INFORMATION
Think-Pair-Share	14	Often used to activate prior knowledge or reflect on the meaning and value of content.
Team	19	Often asked students to apply, analyze, and synthesize information, including interpreting or creating graphs and crafting hypotheses to explain data. Total number includes three activities designed specifically to scaffold students through the research project.
TAKE-HOME ESSAY TYPE		
Individual	2	
Team	3	All designed to scaffold students through the research project.

interactive collaborative activities, and ones that appealed to introverted learners, such as solitary deductive sequences (Jonassen and Grabowski 2012). Additionally, in order to help students integrate their knowledge into a more coherent framework, each class period included time for them to reflect individually, in groups, and as a class on what they were learning and why (Davis and Linn 2000).

Final Project

Although the activities provided the students opportunities to appraise and synthesize information, our ultimate goal for the course was for the students to generate and defend their own research into the twin civic issues underlying the course. To accomplish this, during the last third of the semester we implemented a series of assignments to scaffold students through their collaborative final class project, which culminated in an authentic public event dubbed "Paleocon." This project required teams of students to choose a threatened modern animal and an extinct counterpart and research their habitats, ecosystems, and lifestyles. They evaluated and described how the ancient organism became extinct and extrapolated lessons learned from that extinction event to help the modern organism survive the twin specters of human-caused extinction pressure and climate change. In lieu of a final examination, the teams presented their findings to their classmates, the university, and the general public in a creative science-fair-style presentation.

Outcomes

Throughout the redesign process, we shifted the emphasis of the activities, assignments, and assessments away from simple memorization and understanding to build in more analysis, synthesis, and evaluation of ideas and information. This shift is well illustrated by a general analysis of exam questions by level on Bloom's Taxonomy (Bloom et al. 1956) in the Spring 2012 (traditional) and Fall 2014 (redesigned) semesters, shown in Figure 1. We acknowledge that grades are not a proxy for learning and

Figure 1: Distribution of exam question Bloom's level from Spring 2012 (traditional) and Fall 2014 (redesign). Prior to the redesign, all exam questions were related to the three lowest levels of Bloom's taxonomy (remember, understand, apply), with the majority of questions asking students only to remember content. During the redesign, upper levels of Bloom's taxonomy were incorporated (analyze, synthesize, evaluate) and questions were much more broadly distributed. (Total for 2014 not equal to 100 due to rounding.)

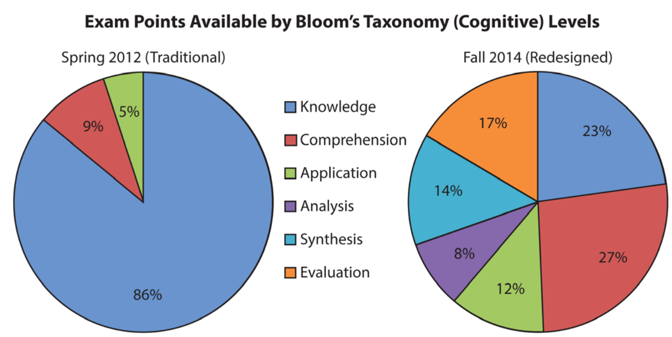


Figure 2: Grade distribution through the years that Geology 121 has been taught by Dr. Olcott Marshall; 2014 is the year the course was transformed. Final letter grades were determined by calculating the percentage of available points earned by each student then converting that percentage to a letter grade with a traditional 10-point scale. The redesigned course resulted in a much greater number of A's and B's and a significantly reduced number of C's, D's and F's.

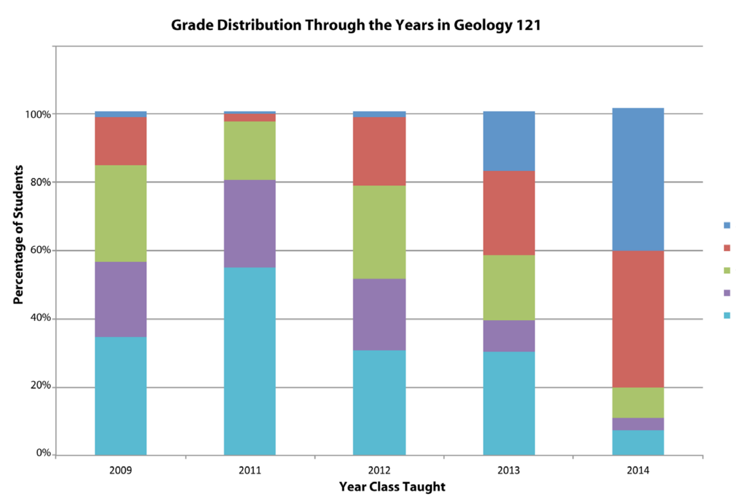


TABLE 2. Types of Activities Introduced in Transformed Class

OLD CLASS QUESTION:	NEW CLASS QUESTION:
The radioactive isotope ^{40}K decays to its daughter atom ^{40}A with a half-life of 1300 million years. If a crystal is found that is 1/16 ^{40}K and 15/16 ^{40}A, was this crystal formed on the Earth? How can you tell?	How old is the Earth? By what methodology might scientists know this age, and why?
Yes, the crystal must have been formed on the earth because it is a radioactive isotope which is often associated with volcanic activity. Therefore the crystal must have been formed on the Earth and was formed by some type of volcanic activity.	Over the years, scientists have come to somewhat of a consensus on how old the Earth really is. After extensive development of ideas, thousands of hours of research, and much speculation, the consensus on the Earth's age is settled on a ballpark figure of about four and one-half billion years. An exact age has not been able to be determined because plate tectonics have destroyed most, if not all, of the Earth's oldest rocks, which were our best means of getting to the root age of our planet (material cited: "Geologic" 2007). Scientists decided that the best way to figure out the Earth's age was by measuring the age of ancient sedimentary rocks and the decay of radioactive isotopes of elements found inside them. The half-lives of these radioactive isotopes are determined by radioactive dating (material cited: "Geologic" 2007). Once we know the actual age of the rock units, scientists are then able to place them along a timeline of Earth's history, known as the geological time scale, and then use the oldest recorded one to also represent the age of the Earth.
No. Because in this problem, you would multiply 1300 million years by 4 (because 1/16 indicates four half-lives) = 5200 million years ago. We have learned that the earth is approximately ~4500 million years old so we know the crystal was not formed on earth	No. Because in this problem, you would multiply 1300 million years by 4 (because 1/16 indicates four half-lives) = 5200 million years ago. We have learned that the earth is approximately ~4500 million years old so we know the crystal was not formed on earth The current best estimate for the age of the Earth is 4.54 billion years. Scientists have used radiometric dating on a variety of radioactive compounds contained in old, undisturbed rocks and iron meteorites all around the globe; as well as on the moon, where ancient rocks are much more plentiful due to a lack of plate tectonic movement that would destroy and remake rock formations (material cited: Watson). Using the known half-lives of these radioactive substances, and collecting samples from the rocks to find how much of the substance has already decayed, scientists can determine an approximate range of the sample rock. This would mean, of course, that the Earth is at least as old as the rock in question (the same logic applies to samples from the moon: the Earth must be at least as old as the oldest rocks found on the moon). Also, other clues from around the solar system, such as calculating the age of the Sun, have helped in reaching the 4.54 billion estimate, since the ages of all heavenly bodies in the solar system are understood to be roughly similar (material cited: Watson).

but it is striking that, although the redesign required the students to do more work and to understand the material on a deeper level than in previous years, student performance (as measured by grades) increased as well, eighty percent of the class earning an A or a B (Figure 2).

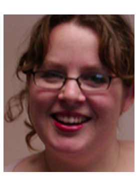
Qualitatively comparing student written work from previous years with that produced by students in the new course demonstrates increases in student engagement and ability to synthesize material on their own (Table 2).

Although the two questions asked are slightly different each year, to answer either question, a student would need to know the age of the Earth and understand the principles of radioactive age dating. In the transformed class, student work reveals a deeper understanding of the material and increased ability to synthesize different types of information than in years past.

Student success, as well as the success of the redesign, are also reflected in the students' attitudes towards the class and the material. Students were initially leery of the changes in the class, as they correctly surmised that they would be doing more work than a traditional lecture-based course would require. They also were, as one student put it, "shocked that they had to be in a group and do so much group work." However, they quickly became much more engaged with the material than in previous years; one student commented that the class "motivates us to want to learn the information and apply it to things that interest us as opposed to just being in the library and studying and then going and taking a test." Or, in the words of another student at the end of the semester: "I expected this class to be somewhat boring and easy but it was anything but that. It provides you with a lot of insight that you can carry on to a lot of career fields. It's a strong base to the information that you will gain in the rest of your collegiate experience."

About the Authors

Kelsey Bitting is a Visiting Assistant Professor and Postdoctoral Teaching Fellow for Course Redesign at the University of Kansas. She is a trained geomorphologist and sedimentary geologist, but her current research interests center on geoscience learning and the implementation of active learning in introductory courses.



Alison Olcott Marshall is a paleobiogeochemist at the University of Kansas. Her research involves using chemistry to quest for and understand fossils, and she has recently become interested in transforming her classes with the hope that students will be excited and involved in their own learning.

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PROJECT REPORT

The Use of Untested Drugs to Treat the Ebola Virus Epidemic:
A Learning Activity to Engage Learners

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Abstract

One objective of this activity is to help students understand an Ebola virus outbreak and epidemic, and particularly how this might affect human life and society within and between various human communities, not only in a given country or society, but also on an international scale. A second objective is to actively engage students in a library investigation, conducting literature research, and collaborating in group work, not only to achieve understanding, but also to retain new information and apply what has been learned to different situations. The aim is to provide an opportunity for students to become deep learners by engaging in active learning. The paper is divided into two parts. Part one provides background on the nature, character, and epidemic of Ebola and the impact of the last outbreak not only on the affected regions, but also on the whole world. Part two is a learning activity that is designed as a role-playing exercise to engage students in research to learn about the biology behind Ebola. They also debate the question of whether or not the use of drugs and Ebola vaccines that have not gone through the clinical trial process should be used to control the epidemic before it can no longer be contained. The willingness to bypass government approval of treatments and scientific and clinical practices demonstrates the severity of this outbreak and the desperation it has caused. Yet there are good reasons why clinical trials are essential in obtaining objective evaluations of the effectiveness of treatments. In conducting research on the topic and engaging students in an informative debate about the matter, we hope to promote deep learning and a lasting understanding of viruses in general and Ebola in particular. An Ebola epidemic is a good vehicle to introduce students to the need for civic and community engagement at the local, national, and global level by extending student learning beyond the classroom and into the community.

Key words: Clinical trial, placebo, enveloped and non-enveloped viruses, retrovirus, Ebola epidemic, treatment group and control group, critical experiment, community engagement, social mobilization, service-learning.

Part I — Ebola: Its Nature, Character, and Epidemic

Introduction

The recent Ebola outbreak in West Africa (Figure 1) has placed various governments, non-government organizations, and communities at local, national, and international levels in situations that they have never faced before. According to the World Health Organization (WHO), if left untreated, Ebola virus disease (EVD), formerly known as Ebola hemorrhagic fever, is a severe, often fatal illness in humans, further spread through contact with bodily fluids (WHO 2014, ¶1). Initial EVD outbreaks typically start in rural areas but quickly spread to urban centers with larger populations, further compounding the need for consideration of human needs and proper scientific investigation (Quammen 2015; Wolinksy 2015).

A dilemma that had previously been considered "unthinkable" seemed to call for desperate measures, including "withholding emergency treatment from infected patients" and using drugs that have not yet gone through clinical trials to treat infection. As a result, hospitals all over the world have started to review their policies on the treatment, handling, and screening of patients with the virus. This is due first to the lack of trained health care workers to care for potential patients, and second, to the high risk of transmission to health care workers in contact with Ebola patients (The Week 2014). Finally, it is important to note that there is a widespread assumption that if an Ebola outbreak occurred in a wealthy developed nation, the response would be swifter and more comprehensive than the current response in affected countries of West Africa (Joanne Lin in Marsa 2016). This assumption only further complicates the ethical issues at hand. Adding to the complexity of the situation is the fact that the "urgency of human needs in an outbreak makes scientific investigations difficult" (Quammen 2015, 52).

The development of therapies to combat the virus has been an ongoing process; "there is as yet no licensed treatment proven to neutralize the virus, but a range of blood, immunological and drug therapies are under development. There are currently no licensed Ebola vaccines, but multiple candidates are undergoing evaluation" (WHO 2014, ¶1). For many human advocates and civic engagement activists, the current medical options available are not acceptable. Lack of insight into the drug development process also results in public distress which further compounds the issue. Furthermore, as Joanne Lin, the president of Médecins Sans Frontières International in Geneva, Switzerland, stated:

> Initially, we told people it's a deadly disease and we have no cure, so essentially we're telling them "Come and die in an Ebola Center." We need to change that because if these people come in earlier, they have a better chance to pull through and not infect their loved ones. We know what to do because it's like HIV and AIDS two decades ago – it was a death sentence, and people hid from it. But today it is not a death sentence, and we need to apply what we learned from fighting that epidemic. (Marsa 2016, 17)

The Biology of the Virus

A virus is a non-cellular infectious agent, typically 20 to 30 nanometers in diameter (Ebola being exceptionally large, at 970 nanometers), which typically consists of a genome encased in a protein coat. As an extracellular entity, it is given the term viroid. The viral genome contains either DNA or RNA. Many viruses have additional structural features, for example, an envelope composed of a protein-containing lipid bilayer, whose presence or absence classifies viruses as either enveloped virus or non-enveloped virus (Strohl et al. 2001; Tortora et al. 2015).

As they lack ribosomes or other necessary protein-making machinery, viruses do not have the ability to grow or replicate on their own, but only do so inside the cells of living hosts by subverting their cellular machinery. They are thus considered obligatory intracellular parasites (Strohl et al. 2001; Tortora et al. 2015). The host cell would be unable to carry out normal function, reproduce, and would typically die. With the ability to replicate within cells of living hosts, viruses are able to generate great diversity, giving rise to various forms, such as RNA virus, DNA virus, viroid, etc. (Rudin 1997, 385). Today, scientists classify viruses into families based primarily on the type of genome, capsid symmetry, and the presence or absence of an envelope (Strohl et al. 2001; Tortora et al. 2015). For example, scientists have identified the families seen in Table 1 below.

The Ebola virus belongs to the family Filoviridae; its members are enveloped viruses with RNA genomes. The Filoviridae family has three genera: Cuevavirus, Marburgvirus, and Ebolavirus. Five species of Ebolavirus have been identified thus far: *Zaire, Bundibugyo, Sudan, Reston*, and *Taï Forest*. *Zaire, Bundibugyo*, and *Sudan* are the Ebola viruses that have been associated with large outbreaks in Africa, with Zaire currently causing the West African epidemic (WHO 2014, ¶2).

The differences within the species of the Ebola virus are significant. The *Reston* species has never caused illness in humans, and researchers have never found definitive evidence of air-based transmission. Zaire Ebola virus, on the other hand, does cause illness in humans. A non-airborne infection, it spreads by direct contact with body fluids (Science News 2014, 30).

Thus based on Table 1, we can summarize that Ebola is

> A member of the Filoviridae family of viruses (so named because the viruses adopt various filamentous shapes), the Ebola virus consists of a single strand of RNA and associated proteins, wrapped in a fatty membrane. Scientists have so far isolated two members of the family — Ebola and Marburg viruses — and grown them in

TABLE 1. Viruses are classified into families based on the type of genome, capsid symmetry, and presence or absence of an envelope (Strohl et al. 2001; Tortora et al. 2015)

Type of Virus	Families	Genetic Make-up	Enzyme Presence
Enveloped Virus	Papovaviridae	Double-stranded, circular DNA	Virions contain no enzyme
	Adenoviridae	Double-stranded, linear DNA	Some contain DNA-dependent polymerase
	Picornaviridae	+Single-stranded, non-segmented RNA	Virions contain no enzyme
	Caliciviridae	+Single-stranded linear RNA	Virions contain no enzyme
	Poxviridae	Double-stranded linear DNA	Contains RNA polymerase
	Flaviviridae	+Single-stranded, non-segmented RNA	Virions contain no enzyme
Nonenveloped Virus	Parvoviridae	Single-stranded, linear DNA	Virions contain no enzyme
	Hepadnaviridae	Circular DNA, parity single-stranded, parity double-stranded, DNA	Contains DNA polymerase and reverse transcriptase
	Herpesviridae	Linear, double-stranded, DNA, circularizes in host	Virion contains no enzyme
	Togaviridae	+Single-stranded, non-segmented RNA	Virions contain no enzyme
	Coronaviridae	+ Single-stranded linear RNA	Virions contain no enzyme
	Rhabdoviridae	-Single-stranded, non-segmented RNA	Contains DNA -dependent RNA polymerase
	Paramyoxviridae	-Single-stranded non-segmented RNA	Some contain RNA polymerase
	Orthomyxoviridae	-Single-stranded, segmented RNA in eight pieces	Contains RNA polymerase
	Filoviridae	- Single-stranded RNA	RNA-dependent RNA polymerase
	Bunyaviridae	-Single-stranded segmented RNA	Contains RNA polymerase
	Arenaviridae	-Single stranded segmented RNA	Contains RNA polymerase
	Retroviridae	+Single-stranded linear RNA—two copies per virion	Transcriptase

http://www.life.umd.edu/classroom/bsci424/BSCI223WebSiteFiles/DNAvsRNAVirusBiosynthesis.htm

TABLE 2. A Typical Example of Viral Life Cycle

A Typical Example of Viral Life Cycle (Garrett and Penn 2009, 197)		
1	Attachment	A specific attraction between a molecule on a virus and a receptor molecule on a host cell
2	Penetration	All or some of the virus enters the host cell.
3	Uncoating	Protein coat is removed if entire virus enters host cell.
4	Biosynthesis	Viral nucleic acid and proteins are biosynthesized by the metabolic machinery of the host cell.
5	Assembly	Viral nucleic acid and the structural proteins assemble together to form new viruses.
6	Release	Virus bursts out of host cell or "buds" out within an envelope of the host membrane.
7	Re-infecting other cells	New viruses infect new host cells

culture. Genes from a third member – Lloviu virus – have been sequenced, but the virus has not yet been fully characterized in a laboratory. Of the five known strains of Ebola, Reston is the only one that apparently does not cause disease in infected people. (Branswell 2015, 52)

The Life Cycle of a Virus

Most viruses exhibit similar behaviors during their lifespan. As shown in Table 2, at each stage the virus tries to accomplish a specific set of tasks. Some viruses undergo a more dormant lysogenic cycle, in which the infection still controls the systems of the cell and often inhibits its function, but does not kill the host cell. In many cases, a cell's death results when the virus takes up the lytic cycle, either after a lysogenic phase or immediately. The steps to replication are described in Table 3.

Like most other untreated viruses, Ebola virus successfully completes replication and generates more copies of itself in four general steps.

1. Using surface proteins Ebola virus recognizes and attaches to cells in the host organism. It fuses with cells lining respiratory tract, eyes, or body cavities, then penetrates the membrane of the host cells and sheds its protein coat.
2. The virus's genetic content (viral nucleic acid [RNA]) is released into the cell and enters the host cell nucleus.
3. The viral genetic material takes over the cell machinery to replicate new viral nucleic acid, which then goes from the nucleus into the cytoplasm and combines with structural proteins to form new viruses. In other words, they become physically and functionally incorporated into host cell (Adams 2014; Hart et. al. 2012).
4. The newly produced copies of the virus are broken off and expelled from the host cell into the system to infect more cells and hijack their metabolic machinery systems to manufacture instead more of the viral components needed to form more of the new viruses.

As the immune and circulatory systems are compromised, the pathogen is free to proliferate and furthermore given new opportunities to affect more people as blood is lost (Branswell 2015, 52). The World Health Organization has strongly argued that the most critical keys to the treatment of the Ebola epidemic include, but are not limited to, the following: civic and community engagement, proper case management, surveillance and contact tracing, good laboratory service, safe burials, and social awareness and mobilization.

TABLE 3. Symptoms of Ebola's Infection

"Ebola virus enters through eyes, mucus membranes, or tiny cuts or scrapes. Symptoms typically appear four to 10 days later" (Lydersen 2015, 9).		
Early Symptoms	Mid-stage Symptoms	Advanced Symptoms
Flu-like symptoms; fatigue, muscle soreness, sore throat, headache, chills.	Severe diarrhea and vomiting; red eyes, spotty rashes and bruises; chest pain, shortness of breath.	Can include bleeding from eyes, mouth, nose, and anus. Seizure; organs fail; shock; coma.

The Reservoir Host for Ebola Virus

Despite having caused dozens of outbreaks in a forty-year span, the Ebola's reservoir host remains unknown. The fact that the virus does not infect very often has possibly kept its genome stable over the years. It has not had many opportunities to mutate, causing infrequent outbreaks with a low genetic diversity (Quammen 2015). From 1977-1994, no human death as a result of Ebola was reported, and researchers have concluded that the reservoir host for Ebola virus must be non-human because of high fatalities from human infection. Ebola cannot be circulating in the human population latently; it must reside in a non-human host so that when it spills over into another species it causes deadly disease.

In searching for a reservoir host, researchers have ruled out chimpanzees and gorillas, because they have also died from becoming infected with Ebola virus. When there have been Ebola disease outbreaks in humans, carcasses of chimps and gorillas have been found nearby, and some have tested positive for signs of the virus (Quammen 2015). Coming in contact with these carcasses for food has been one way in which populations initially contract the virus. Based on disease outbreak trends and research studies, it was found that the fruit bat from the Pteropodidae family and the Angolan free-tailed bat are a possible reservoir for Ebola (Quammen 2015; WHO 2014). People who use fruit bats as a food source or who come in contact with them do become infected.

In 1976, two outbreaks of Ebola virus disease occurred parallel to each other, in regions about one thousand kilometers apart in central Africa. One outbreak appeared in Nzara, Sudan, and the second in Yambuku, Democratic Republic of Congo. The recent epidemic is the greatest and most complex Ebola outbreak since its discovery, leading to more cases and deaths than all other outbreaks combined. It has spread to other countries, starting in Guinea and spreading across land borders to Sierra Leone and Liberia (Figure 1). It has also spread by air to Nigeria, and by land to Senegal. Guinea, Sierra Leone, and Liberia are the countries that have been most severely affected. Even as the number of cases for the 2015 outbreak decreases, a resurgence of cases has occurred due to survivors continuing to pass on the disease after recovery (Farge and Giahyue 2015). Weak health systems, lack of human and infrastructure resources, and having recently emerged from periods of conflict have further contributed to the devastating impact that the Ebola virus disease has inflicted.

How is Ebola Virus Spread Amongst Humans?

The time it takes the virus to kill an infected individual depends on how it enters the body and how much virus the person has been infected with. Any form of contact with bodily fluids, either directly or through syringes, is the likely mode of the spread of the virus. Once inside the host, Ebola virus primarily targets dendritic cells and macrophages to replicate its RNA. The virus forces these cells to produce and secrete free-floating glycoproteins that resemble its own surface glycoproteins. These secreted glycoproteins become the target of the immune system cells and effectively cause a distraction in which the virus can continue to infect other host cells and proliferate. Macrophages and dendritic cells circulate in the body and phagocytize foreign organisms or damaged cells. When the virus infects these cells, it is able to travel to various points of the body and wreak havoc when it replicates. Researchers believe that the severity of the virus infections in large human populations is due to these mechanisms. For individuals who are immunocompromised or malnourished, the virus can have an even greater advantage in taking over the already weakened immune system and thus have a greater chance of proliferating.

In short, all the evidence indicates that "Ebola isn't nearly as contagious as measles and many other viruses. … and a person infected with Ebola may not show any symptoms for 21 days" (Adams 2014 9–10). However, as the recent outbreak has shown, Ebola is not a subtle bug. It "…kills many of its human victims in a matter of days, pushing others to the brink of death, before vanishing" (Quammen 2015, 40). Bray et al. (2015) have summarized the symptoms and signs of disease as follows:

> Patients with Ebola virus disease typically present with a nonspecific febrile syndrome that may include headache, muscle aches, and fatigue. Vomiting and diarrhea frequently develop during the first few days of illness, and may lead to significant volume losses. A maculopapular rash is sometimes observed. Despite the traditional name of "Ebola hemorrhagic fever," major bleeding is not found in the majority of patients, and severe hemorrhage tends to be observed only in the late stages of disease. Some patients develop progressive hypotension and shock with multiorgan failure, which typically results in death during the second week of illness. By comparison, patients who survive infection commonly show signs of clinical improvement during the second week of illness. (Bray et al. 2015, ¶2)

Treatment of Ebola is primarily aimed at mitigating the effects of the symptoms that arise as the disease progresses (King 2015). Necessary precautions are followed by the caregivers and healthcare staff to eliminate unnecessary exposure of the patient and prevent harm to self. As resources permit, the overall state of the patient in vital signs, fluid levels, and electrolyte levels is carefully monitored and remediated appropriately, especially in the earliest stages of infection. Some medication may be administered if the patient is strong enough, such as antipyretic agents, analgesics, antiemetic, anti-motility, and anti-epileptic medication. At the height of the onset of the more severe symptoms, more invasive interventions must be given, such as intubation (for respiratory failure), dialysis/renal replacement (for kidney failure), and antimicrobial therapy (for co-infecting diseases, such as malaria) (Bray et al. 2015).

Ebola virus survivors are not safe either; as Kupferschmidt (2015) has recently reported, there is a growing and alarming trend in Ebola survivors displaying health problems after they have fought the disease. Not only do these individuals suffer from emotional and psychological problems, they also suffer from post-Ebola syndrome, such as headaches and memory and vision problems. It is believed that the symptoms may arise from cells and organs that were damaged by the virus before it was brought under control (Kupferschmidt 2015). The side effects could be caused by the immune system trying to fight the virus, or the immune system could have turned against its own tissues with host molecules similar to Ebola.

To learn more about the clinical manifestations and diagnosis of Ebola virus disease, instructors can direct students to the work of Bray and Chertow (2015), which provides an update about this matter.

The Role of Clinical Trials in Determining the Effectiveness of a Drug

In Guinea, a clinical trial is being conducted for an experimental Ebola vaccine that is yielding promising results. More than 7,651 individuals were involved in the study, and over 3,400 received the vaccine. Individuals who were vaccinated were those who came in contact with Ebola infected patients, as well as the contacts of those contacts. Some people were vaccinated immediately and others were vaccinated after 21 days. The individuals who were immediately vaccinated were found to not contract the disease, whereas some who were vaccinated twenty-one days after contact with Ebola infected patients developed the disease. This might have occurred due to the nature of the virus incubation period, which is twenty-one days. Although significant, these results are preliminary; further research and monitoring must be performed to test the efficacy of the vaccines over time. The side effects to the patients were reported to be minimal (Fink 2015; Seppa 2015).

The Public Health Agency of Canada created the vaccine by combining a piece of the virus's covering and

TABLE 4. Summary of Current Ebola Treatments in Development

Drug / Vaccine	Description	Status
ZMapp	"ZMapp™ is composed of three "humanized" monoclonal antibodies manufactured in plants, specifically Nicotiana. It is an optimized cocktail combining the best components of MB- 003 (Mapp) and ZMAb (Defyrus/PHAC). ZMapp™ was first identified as a drug candidate in January 2014 and has not yet been evaluated for safety in humans. As such, very little of the drug is currently available" (Mapp Biopharmaceutical, Inc . n.d.).	Granted fast track status by the FDA
TKM-Ebola-Guinea	"...a modified RNAi therapeutic, based on the Company's original TKM-Ebola investigational therapeutic, to specifically target Ebola-Guinea. The new product, termed TKM-Ebola-Guinea, is designed to match the genomic sequence exactly, with two RNAi triggers" (Arbutus Biopharma 2015).	Discontinued after poor efficacy in trials.
Favipiravir (Avigan)	"The anti-influenza drug Avigan® Tablets was developed by the Fujifilm Group company Toyama Chemical Co., Ltd. Results of mouse experiments showing the antiviral effect of Avigan® Tablets against EVD have been published, and Avigan® Tablets have already been administered as an emergency response to multiple patients infected with EVD. The production of Avigan® Tablet 200mg for the treatment of Ebola Virus Disease" (Fugifilm 2014).	Trials show early promise but are in danger due to lack of patients.
Brincidofovir	"...brincidofovir (CMX001), a clinical-stage nucleotide analog lipid-conjugate, which has demonstrated potent antiviral activity and safety in convenient, orally administered dosing regimens. Chimerix is currently enrolling SUPPRESS, a Phase 3 study of brincidofovir for the prevention of cytomegalovirus (CMV) in adult hematopoietic cell transplant (HCT) recipients. In addition, Chimerix is enrolling the Phase 3 AdVise trial of brincidofovir for treatment of adenovirus (AdV) infection" (Chimerix 2015).	Trials for use in Ebola have been discontinued to due lack of patients.
VSV-EBOV (vaccine)	The experimental vaccine is based on an animal virus called vesicular stomatitis virus (VSV) that is combined with a portion of the protein covering of the Ebola virus. When administered, it induces an immune response against the Ebola virus" (Public Health Agency of Canada 2015).	In Phase III Trials with very promising results.
BCX4430	"...BCX4430, a novel synthetic adenosine analogue, inhibits infection of distinct filoviruses in human cells. Biochemical, reporter-based and primer-extension assays indicate that BCX4430 inhibits viral RNA polymerase function, acting as a non-obligate RNA chain terminator. Post-exposure intramuscular administration of BCX4430 protects against Ebola virus and Marburg virus disease in rodent models" (Warren et al. 2014, 402).	Awarded Advanced Development in 2015 by U.S. Government to support clinical trials.

an animal virus to set off an immune response against Ebola (Fink 2015). The results of this and other clinical studies are expected to be analyzed and scrutinized so that the vaccine can be approved by the Food and Drug administration (FDA). If approved, this vaccine would completely change an Ebola crisis by preventing the development of new Ebola cases in the vaccine's recipients. A summary of current experimental Ebola treatments has been compiled in Table 4 below.

Clinical trials are a critical part of doing science involving people. It is these trials that decisively determine whether a particular treatment is effective by testing the drug in a "treatment" group and in a "placebo control" group. If the tested drug is not effective, we will be able to show empirical evidence that it has failed and reject it with statistical confidence. After all, science, through the scientific method approach, is an efficient and objective pathway by which we can discover and better understand the world around us" (Cherif 1998; Cherif and Roze 2013; Phelan 2013). As defined by the National Cancer Institute (NCI) (2014 a and 2014b) at the National Institutes of Health (NIH), clinical trials are research studies that involve people, test new ways to prevent, detect, diagnose, or treat diseases, and thus contribute to our understanding of the world in which we live. It is an effective approach when research studies involve people because it is empirical, testable, repeatable, and self-correcting. In short, the clinical trial is "a device for obtaining objective evaluations of the effectiveness of treatments" (Fehan 1979, 32). Because of this, policies and regulations at the national and international level have been developed to protect the rights, safety, and well-being of those who take part in clinical trials. They also ensure that trials are conducted according to strict scientific and ethical principles. Through informed consent people learn about the clinical trial so they can decide whether they wish to participate (NCL 2014a, ¶1).

Furthermore, people who take part in any type of clinical trial have an opportunity to contribute to scientists' knowledge about a given targeted disease and to help in the development of improved treatments for that particular disease (e.g., cancer, HIV) (NCI 2014a,¶2). When it comes to Ebola virus, the stakes are very high, since both the rate of infection and the rate of death from infection are extremely high. Adding to this complex equation of urgency is that fact that to date there is no licensed effective drug on the market for people to use with Ebola epidemic.

The WHO Director-General declared this outbreak a public health emergency of international concern, but the UN's Anthony Banbury predicted that the Ebola outbreak would end in 2015 (NBC News 2015b). The World Health Organization (WHO) declared the end of the Ebola outbreak in Liberia in September 2015, Sierra Leone in November 2015, and in Guinea in December 2015, two years after the epidemic began there. However, this good news has been interrupted by the thought among a number of experts that the problem might still be around. This might be why Alexandre Delamou, Chief of Research at the National Center for Training and Research, Maferinyah, stated:

> Guinea Ebola's lasting legacy may be in maternal and child health: Public health officials worry that deaths during childbirth and from preventable childhood diseases like measles could escalate into the tens of thousands. Delamou talks about why the collateral damage triggered by the epidemic could turn out to be even more lethal than the outbreak itself. (Marsa 2016, 16)

Because of this, the recent Ebola epidemic is an ideal vehicle to introduce students to the need for civic engagement, global awareness, and social mobilization at all levels of involvement. It is also a good topic for extending student learning beyond the classroom and into the community and for helping students develop a sense of caring for others and a desire to meet actual community needs (Belbas et al. 2003). Public awareness, education, civic and social engagement, and global mobilization are urgently needed at all levels as part of both the treatment and prevention of the Ebola epidemic.

Part II Learning Activity

To Use or Not To Use Clinically Untested Drug for Ebola Treatment

One objective of this activity is to help students understand the Ebola virus's effect on societies and communities. The second objective is to actively engage students in a library investigation, conducting literature research, and in collaborating in group work, not only to achieve understanding, but also to retain new information and apply what has been learned to different situations. The aim is to provide an opportunity for students to become deep learners by engaging in active learning and civic engagement (Cherif et al. 2011). As Houghton (2004) has argued, deep learning promotes understanding and application for life and "involves the critical analysis of new ideas, linking them to already known concepts and principles, and leads to understanding and long-term retention of concepts so that they can be used for problem solving in unfamiliar contexts" (Houghton 2004, 5).

In this role-play learning activity, the class is divided into nine groups of three or four students each. The members of each group will engage in focused research, meet several times to formulate their chosen perspective, and revise strategy and plan on how they are going to introduce their own perspective, supported with convincing informative arguments. The task of each group's members is to come up with an agreed-upon perspective that reflects their collective informed opinions about their specific issue and to defend it against other groups' perspectives.

Scientifically, any drug intended to be used with people is tested with two separate groups of patients; one group is given the actual drug, and the other group is given a placebo. The members of both groups do not know whether or not they are taking a placebo drug.

A placebo is "an inactive substance used in controlled experiments to test the effectiveness of another substance; the 'treatment group' receives substance being tested, the 'control group' receives the placebo."(Norris and Warner 2009, vlg-2)

The Scenario—The Problem

Clinical trials are research studies designed to assess the safety or efficacy of a medical product including medicines, procedures, treatment and/or intervention and to determine which one may benefit the targeted patients the most. To successfully ensure obtaining objective outcomes, these types of research studies often involve expert teams from the academic, governmental, and pharmaceutical sectors. As a result of this, clinical and medical trials are often funded by both government agencies such as NIH and industries. Furthermore, the 1993 Revitalization Act requires that *"all federally funded clinical research prioritize the inclusion of women and minorities and that research participant characteristics be disclosed in research documentation"* (Basken 2015; Ehrhardt et al. 2015).

No one can statistically guarantee the drugs will work on humans or predict their effect on humans without evidence from clinical trials. Two opposing views arose from this standard in light of the outbreak. On the one hand, the government and the medical communities were asked to follow the agreed-upon experimental procedures of using "treatment groups" and "control groups" to test the drugs on human subjects regardless of the epidemic's severity and how many people were in real need of any available drug to try. Those who argued this were well aware that the "treatment group" receives the substance being tested, while the "control group" receives the placebo. On the other hand, there are many dissenting opinions arguing that in an epidemic such as this, we cannot afford to wait for a given drug to be tested on humans, since it will take months or potentially years to determine its efficacy and long-term effects. In addition, using the placebo with a group of people infected with the Ebola virus might result in most of them missing an opportunity to get the potential drug and recover.

The question then becomes: should or should we not authorize the administration of the three drugs that are not yet tested through clinical trials on humans? In other words, because of the severity of the epidemic, should we skip the clinical trials and the use of the "treatment group" and the "control group" to first test the effectiveness of the drugs before using them on all Ebola patients? This is a learning activity in which students will engage in active learning to deal with this ethical dilemma, which is faced not only by the countries that are affected by the current Ebola outbreak, but by countries worldwide where similar epidemics are possible.

In this learning activity:

1. Students are asked to conduct research regarding the following:
   a. Learn about the Ebola viruses and how they are different from other viruses.
   b. Learn how Ebola virus infects people, the myths and facts about an Ebola outbreak, and the modes of transmission between people.
   c. The distribution of the Ebola epidemic worldwide, past and present.
   d. The symptoms and the signs of the Ebola infection and how the people infected with virus can be treated.
   e. The types of drugs and treatment therapies that are available for Ebola patients to use.
   f. How effective the treatment of people infected with Ebola virus is in various countries.
   g. The effectiveness of the available treatment therapy for Ebola infection and Ebola virus.
   h. Clinical trial experimental procedures and their critical role in determining the safety and effectiveness of a given drug for a given illness.

2. Based on their research findings, the members of each community (group) formulate their informed and supported perspective on the use of untested drugs for the treatment of patients who are already infected with Ebola virus.
3. When the members of each group have developed their own informed perspective, they engage in a

debate with the members of the other communities (groups).

The Communities

The class is divided into the following nine groups (communities):

- The scientific community
- The legal community
- The pharmaceutical community
- The civic engagement and activist community
- The local community
- The government and political community
- The medical community
- The board debate committee
- The media group

Each community consists of three or four students. The members of each community work together for three weeks to conduct research using the questions that have been presented to all the communities as a starting point. In the fourth week, the members of each community meet together to finalize the outcome of their research and research paper, as well as their own strategy for how they will present their adopted informed perspective that reflects their collective thoughts about the issue at hand. The members of each group will then argue this perspective, in a face-to-face debate with the other communities. The members of each community will write and submit to the instructor a three- to four-page paper on their research, in which they will explain where they stand and why, on the use of drugs that have not yet been tested in clinical trials in general and in the treatment of Ebola in particular.

The instructor of the class reads all the papers, provides feedback, and raises challenging questions, if needed. Then the instructor gives the students one week to work on their paper again, using his/her feedback, and informs them about the day of the debate. The instructor tells the students in each community to prepare

1. A one- or two-minute written statement that will be read at the beginning of the debate.
2. A one-minute closing written statement that will be read at the closing of the debate, to support their own perspective.
3. A few key points that represent the core of their main argument.
4. Any illustrations, diagrams, or figures that might be useful in helping them to convey their own point of view.

Pedagogical Strategies

The activity can be assigned as a group research project, individual term paper, or as a class presentation. Students may be asked to communicate with scholars in related fields, such as pharmacists, virologists, politicians, lawyers, judges, psychologists, sociologists, medical doctors, scientists, and community advocates, and the activity can be conducted in courses teaching such subjects.

Conducting the Learning Activity

Before the Activity

Instructors and teachers might want to use the following questions to help students start their search.

1. Research three different viruses including Ebola and then write one informative page distinguishing between the three of them. Submit your outcomes to your instructor and prepare yourself to talk about it in the class.
2. In scientific research that focuses on drug discovery, use, and effectiveness, such as in cancer, influenza, malaria, Ebola, etc., there are clinical trials that differ according to their primary purpose. Conduct research to find out if there are also types of clinical trials in Ebola treatment research that differ based on their primary purpose. Use the table below to report your findings.
3. Distinguish between airborne transmission and non-airborne transmission of the virus.
4. Provide three examples of airborne pathogens and foodborne pathogens.

TABLE 5. Are There Different Types of Ebola Vaccine Clinical Trials?

Different types of Ebola vaccine clinical trials		
1	Treatment	
2	Prevention	
3	Screening	
4	Diagnostic	
5	Quality of life or supportive care	

TABLE 6. Explaining the Meaning of Selected Terms to Non-science Person

	Selected Terms	Meaning
1	Placebo	
2	Experimental group	
3	Control group	
4	Placebo effect	
5	Blind experimental design	
6	Double-blind experimental design	

5. Explain which of the following terms best define a virus: pathogenic, microorganism, infectious agent, all of these, none of these.
6. Search the meaning of each term in Table 5, and then write one page distinguishing between Placebo, Experimental group, Control group, Placebo effect, Blind experimental design, Double-blind experimental design, Critical experiment. Based on your research, can you think of two more terms that are related and important to include into the list? In your writing, keep in mind that you are writing to someone who doesn't have your knowledge and is from a non-science field.
7. It has been stated that it is more challenging to create a new drug or vaccine for the treatment of a viral infection than for a bacterial infection. Conduct some library research to investigate the validity of this claim.

Procedures

I - Before the Enacting Procedures

1. Divide the class into nine groups. Each group consists of a leader plus a few members based on the nature of the community and the needed number for adequate representation.
2. Present to the students the scenario that the drugs to treat Ebola have not been tested on humans in any rigorous experiments to determine their efficacy and safety—no one can guarantee they will work on humans—as well as what might happen as a result of taking these untested and unapproved drugs. This dilemma naturally results in two camps arguing the case for or against the use of these clinically untested drugs.
3. Inform the students that as active members of their respective communities, they are to present their stance on the use of the drug candidates for treatment. They should identify the significance of making the

right decision and understand how their decision is the best for their community. They should also predict how their respective communities will react to their final choice and decision.

4. Give the groups two to three weeks to prepare for their class presentation. In addition to working outside class time, students should have ten to fifteen minutes of class time each week for the members of each group to join together and discuss their work and preparation. This will ensure continuous progress on the project.
5. Ask the members of each group to meet and divide the roles among themselves by selecting a leader for each category, as well as which areas within that category they would like to represent. In addition, the members of a given group must make their own choice about the type of decision they would like to take, support, and advocate. This type of involvement is very critical in ensuring high level of student involvement in the learning activity.
6. For the presentation, each group must

    a. Have a well-researched presentation and strategy of how to present their respective community's views and reaction to the decision they would like to make.
    b. Explain their respective community's views and reaction to the decision they would like to make.
    c. Explain how the public might react to their respective community's views and reaction to the decision they would like to make.
    d. Prepare a well-researched student hand-out as well as an illustrated poster.
    e. Integrate the use of technology such as PowerPoint, animations, interactive activities, etc. into the presentation. Students should present their plan and strategy, show how it will work, and convince everyone that their decisions support their community's beliefs and understanding.

II - During the Presentation

1. The groups take turns presenting to the whole class the significance of their decision as well as the prediction of how their respective communities would react to it, including why this is a good decision for both the infected and the community.
2. The leader of each group introduces the members of his or her team, and provides a brief introduction. Then the leader of the group can call on the members of his or her group to talk about the significance their decision as well as predict how their respective communities would react to their decision.
3. The members of the other groups can ask up to three questions after a given group finishes their presentation. The members of each group must also take note of all the questions that were asked by all the groups.
4. When all the groups finish their presentations, the media group reports on the events and provides a list of questions that the members of the communities failed to raise, answer, or avoided discussing.

III - After the presentation

1. Following the class meeting, the members of each group (community) bring answers to the questions that are raised and presented to them by the media group.
2. Each group is given three to five minutes to address the class one more time. In this short final remark, the groups must have a written statement that can be read to support their views and understanding. The written statement doesn't have to be shared with the other groups beforehand. This is a very important stage in the activity and is related to the "Creative Domain" of McCormack and Yager's (1989) taxonomy for science education, as we will see in the assessment section and in Table 6 below.
3. After all the groups present their final remarks, the groups are asked to evaluate, in writing, the performance of each group.

Homework Learning Activity

In this learning activity, students are provided a copy of Table 1 and given one week to conduct library research to answer the following questions:

1. Differentiate between viruses, viroids, prions, and bacteria.
2. Why we often include viruses, viroids, prions with microbes, but we don't qualify them as "living" entities.
3. What type of virus would you choose to work with or on? Describe its structure and explain why you selected this particular virus.
4. If you have the means, the know-how, and the will, what would you:
   a. Add to the existing structure of the virus and why?
   b. Take out of the existing structure of the virus and why?
   c. Modify in the existing structure of the virus and why?
5. What is/are the reason(s) why some viral infections, such as AIDS virus, are incurable?
6. Conduct Internet research to investigate the claim that the Junck DNA in our chromosomes may have come from ancient viruses that managed to insert their hereditary blueprint into our ancestors' DNA (Shukman, 2012).
7. What right do we have to go and tell people what type of drug or treatment they must take? What if they choose not to follow our advice when there is a potential community risk involved? Explain.
8. What have you learned from this learning activity?

Assessments

McCormack and Yager's (1989) taxonomy for science education is both formative (conducted during instruction) and summative (conducted at the end to measure what has been learned). It provides a good framework for assessing students' achievement, performance, and understanding, as well as the effectiveness of the activity. Table 6 below summarizes McCormack and Yager's (1989) taxonomy for science education. We have found this to be very effective in enabling both teacher and student to explore how and why each group reached their decision, and whether this whole situation could have been approached in other ways (Joyce and Weil, 1986). Furthermore, Tables 8, 9, and 10 in the appendix section have been used successfully as tools to record information and to monitor the level of cognitive involvement of the members of a given group during role-play learning activities. For example, using Table 7, instructors can record the type of questions being asked by the members of a given group as well as the relevancy of the questions to the subject matter and to the point being addressed. In addition, using table 8, instructors can record the number of questions being addressed to the other groups by the members of a given group. Instructors can use Table 9 to record the type of questions or conditional statements and their value for assessment purposes (Cherif et al. 2009).

Pre- and Post-test Homework Assignments

To reinforce the learning objectives of the activity and to allow for compelling attitudinal change, ask the students to answer the following questions (adapted from Cherif et al. 2015), either individually or in groups.

I. Pre-test Homework Assignment

1. What will you do to make sure that the perspective and the reaction of your chosen community would be the one favored by each student in your class?
2. What will you do to make sure that you are selecting the right categories of representatives within your chosen community?
3. If you decide to adopt a real and well-known person from your community, what will you do to make sure that you are selecting the right category of representatives within your chosen community?
4. What do you think you will learn from the activity at both the academic and personal levels?

II. A Post-test Homework Assignment

1. What have you learned from the activity at both the academic and personal level?
2. If you had to do this all over again, what would you change or do differently and why?

TABLE 7. Summary of McCormack and Yager's (1989) Taxonomy for Science Education as a Framework for Assessment

	Domain	Description	Type of Questions That Can be Looked At
I	Knowledge Domain	Students acquire knowledge of the subject, an understanding of relationships between the bodies of knowledge, and give reasons for their approach to solving the problem.	What concepts did students learn and how well did they understand them? How well did the students integrate knowledge from different subject areas? To what extent did students demonstrate the understanding of multiple relationships of various bodies of knowledge? Were the students able to disprove or verify some of the supporting theories used in the role-playing activity? What kind of explanations did students offer for the relationship they observed and understood?
II	Process Domain	Students learn how to collect, organize, and analyze data; develop strategies for building rational arguments and thoughts; state problems and generate valid conclusions; participate in team-work; interpret meaning from the project.	How did members of a given group compile data and information? Was there cooperation in putting the information together? How efficient was each group in presenting and communicating the collected data and information? Was their delivery of statements and arguments smooth and coherent? How well did the students use knowledge meaningfully? Did all members participate in the activity?
III	Creative Domain	Students apply creative thinking to the project; cultivate the ability to recognize, evaluate, and use data and information provided by the other parts of the role play; learn to modify a given design as needed.	In what new ways did students use objects and ideas generated during the enactment of the role playing to enlarge their understanding? How imaginative were students in identifying relevant problems and solutions, and conceptualizing new ideas?
IV	Attitudinal Domain	Students learn to listen closely and comprehend the other parts of the role playing. They also learn cooperation in a group performance and self-evaluation.	How persuasive were group members in articulating their positions in order to change the attitudes of the others? How effectively did each group function? Did students' sensitivity and respect for others develop during the process? Did members of a given party demonstrate skills and abilities to resolve conflicts with others constructively? How might each group have functioned more effectively?
V	Application and Connection Domain	Students learn to generate alternative approaches, problem-solving strategies, and solutions.	Did they come up with practical and workable solutions? To what extent did the students utilize their personal experiences and collective group understanding in making decisions related to the activity? How well did the students integrate knowledge from different disciplines in problem-solving strategies? How well did the students learn to negotiate constructive solutions to conflicts?

3. Knowing what you already know, how would you argue against the perspective and the predicted reaction of your own community?

4. If you have selected an actual well-known person from your chosen community, how did this help you to convey the perspective of your community?

5. It has been claimed that finding the right drug to treat illnesses that are caused by viruses presents a more difficult problem than treating illnesses caused by bacteria, because of the potential and the rate of damage to the host. Based on your research, explain why and how. Research what scientists have been doing to overcome that type of obstacle and challenge

when searching for the right drug to treat illness caused by viruses.

Final Remark

As teachers and mentors we need to keep in mind that learning activities and teaching approaches should always aim to capture the students' interest and spark motivation for learning and knowledge creation among students. To achieve this, students should be given the opportunity to be involved in the planning, implementation, and assessment of a given learning activity. To make the teaching approach of the given learning activity more productive, teachers should lead students toward greater levels of involvement in the process by including them in planning the five factors that make up a typical role-playing situation: 1) the problem to be solved; 2) the characters to be played; 3) the roles to be followed; 4) essential information to be gathered and; 5) procedures for the play to be adapted (Cherif and Somervill 1994 and 1995). In this activity, the problem to be solved and the characters to be played are given to the students. However, the roles to be followed, the essential information to be gathered, and the procedures for the play to be adapted as part of the learning activity are the students' responsibility.

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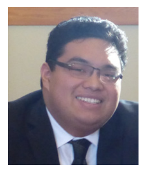

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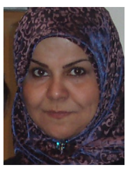

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Appendix

FIGURE 1. West African Countries

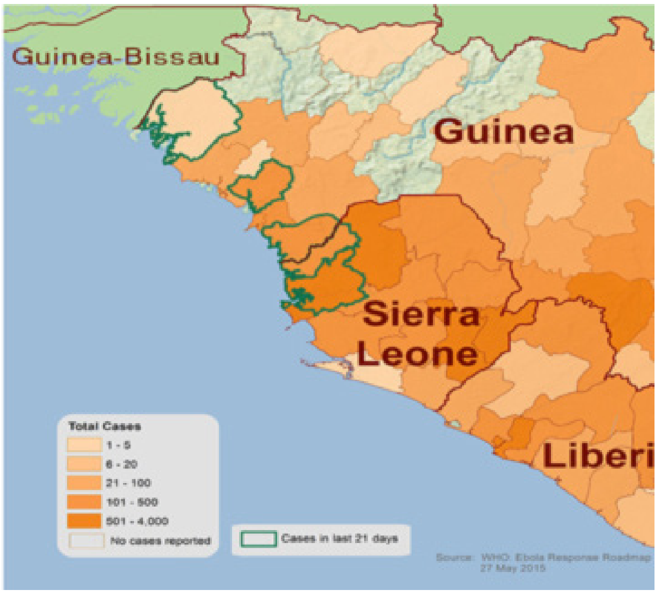

TABLE 8. Individual group questions analysis and account (Cited from Cherif et al. 2009, 350)

	Type of Question or Conditional Statements	Extremely Relevant	Relevant	Less Relevant	Not Relevant	Not Relevant
1.	Why					
2.	How					
3.	What do you think if...?					
4.						
5.	Which					
6.	What					
7.	When					
8.	Where					
	Is/Are					
	Total of questions and or wondering statements					

TABLE 9. Tracking the number of questions asked by each group of other groups

	Scientific community	Legal community	Pharmaceutical community	Politicians & policy makers	Civic engagement	Medical community	Public advocates	Media Group
Scientific community	x							
Legal community		x						
Pharmaceutical community			x					
Politicians and policy makers				x				
Civic engagement					x			
Medical community						x		
Public advocates							x	
Media Group								x
Total of Questions								

TABLE 10. Type of questions or conditional statements and their values for assessment purposes

Type of Question		Why How	What do you think if	Which	What Where When	Is Are	Total
EXTREMELY RELEVANT	# of Questions						
	Value per question	5	4	3	2	1	
	Total Values						
RELEVANT	# of Questions						
	Value per question	4	3	2	1	0.5	
	Total Values						
LESS RELEVANT	# of Questions						
	Value per question	3	2	1	0.5	0	
	Total Values						
NOT RELEVANT	# of Questions						
	Value per question	1	1	0.5	0	0	
	Total Values						
TOTAL							

PROJECT REPORT

Why We Should Not 'Go It Alone': Strategies for Realizing Interdisciplinarity in SENCER Curricula

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Abstract

With support from a SENCER Post-Institute Implementation sub-award grant, seven faculty members from six different disciplines began a collaborative partnership to design joint curricular projects across courses and departments on the theme of Food for Thought. To meet our goals, we developed shared learning outcomes for students in courses in the Food for Thought cluster, using SENCER goals as a guide for our work. In order to address those outcomes, we crafted a variety of projects engaging students from two or more courses. We implemented these projects in our courses and assessed student perceptions of learning and student performance in integrative learning. In this article we detail the challenges and benefits of ongoing interdisciplinary collaboration, as well as how this group of faculty members balanced other demands of academia. We conclude with a discussion of our assessment methodology and findings of improved learning.

Introduction

In most of our academic lives as faculty, many of us are used to, and perhaps even prefer, working alone. We can easily empathize with our students who complain about the hazards and time drain that they experience doing group work in classes. Some of us might go so far as to say we'd rather go it alone than ever have to adjust to planning our teaching with others. After all, when we do it alone, course planning can take place in the wee hours, does not require multiple meetings, and affords us the greatest flexibility and control over what happens in the classroom.

In spite of this tendency to be quite content to "go it alone," our group of seven faculty members has spent the last eight years in a collaborative partnership designing joint curricular projects across courses, departments, and university divisions on the theme of Food for Thought. We work in diverse disciplines— Biology, Chemistry, Economics, Sociology, Spanish, and Health and Wellness— and together we have created numerous projects involving as few as two and as many as five courses that engage students with the science, politics, and human elements of food production, distribution, and consumption. We have not only implemented these multidisciplinary projects in our courses, we have also assessed student perceptions of learning and student performance in integrative learning achieved from this focused, yet multidisciplinary teaching. And while our efforts have taken time and energy, we have evidence, both from our multiple modes of assessment of the effects on students and from the rewards we have experienced teaching in these contexts, that mindfully planned collaboration has important benefits for our work with students.

Our motivation for doing this work occurs in a larger context in which, for more than a decade, universities and colleges across the United States have been newly articulating the value and purpose of undergraduate education. One outcome of this self-interrogation has been a renewed focus on integrative learning and new efforts to work towards assuring that undergraduates leave college with a sense of the complexities of social, scientific, technical, and environmental problems, and with an understanding that problem-solving requires multiple perspectives. In 2004, for example, Carol Geary Schneider, president of the Association of American Colleges and Universities (AAC&U), called for integrative approaches to become more central to the enterprise of education, in order combat the "fragmentation of knowledge" (Schneider 2004). AAC&U has taken on several initiatives related to these concerns, including issues of implementation and assessment (Huber et al. 2007; Ferren et al. 2014/2015). Our work was inspired by our participation in a Summer Institute sponsored by The Science Education for New Civic Engagements and Responsibilities (SENCER), an NSF-funded organization whose focus echoes these concerns about integrative education. Its SENCER Ideals include "robustly connect[ing] science and civic engagement by teaching 'through' complex, contested, capacious, current, and unresolved public issues 'to' basic science" (SENCER 2015).

In this essay, we share our experiences with collaboration in planning, implementing, and assessing cross-course projects that, when experienced by students especially over several semesters, lead to enhanced integrative, interdisciplinary learning. In this context, we define our teaching efforts as multidisciplinary, because projects are approached from each faculty member's traditional disciplinary area of expertise. We argue that a viable approach to the goal of promoting citizen science (science broadly accessible to informed citizens) is to draw on the strengths of multiple experts from more than one discipline, rather than retraining ourselves in realms of expertise that are not our own. Yet we also describe and demonstrate that student learning from this approach is integrative and interdisciplinary, as students are better able to synthesize content and make connections between multiple disciplines. If the goal of a "SENCER-ized" curriculum is to help students learn science and its relevance to and limitations in a range of public issues and in solving complex problems of interest to students, we argue that we enhance these goals by bringing in multiple disciplinary perspectives with real representatives of those lenses. If we forgo "going it alone," we bring more context and connection to civic issues and provide a model of civic engagement for our students.

Cross-Class Collaboration to Promote Interdisciplinary Learning

In 2006, with the help of a SENCER Post-Institute Implementation sub-award grant used to provide faculty summer stipends for planning, we embarked on a path of collaboration, creating a cluster of courses focused on developing the student as an informed consumer of food by providing a platform for discussion of what we eat, why we eat, where our food comes from and its journey from production to consumption, and how food affects our bodies and health. As faculty from across the university in natural sciences, social sciences, and humanities, we sought to create a set of offerings that would meet a multidisciplinary general education requirement[1] by inviting our students to recognize and appreciate the different ways that our disciplines were concerned with issues of food. We hoped to encourage students to recognize ways in which human bodies and societies are interlinked by numerous processes, many of which can be understood by investigating the dynamics of food in chemical, biological, cultural, and social systems. Our primary goal for students was to create an enhanced, interdisciplinary understanding of the interplay of these systems and a more attuned sense of how food is a civic issue.

To meet our goals, we developed a set of shared learning outcomes (Table 1) for students in courses in the Food for Thought cluster. We based these on SENCER Ideals of civic engagement, focusing on contested issues and encouraging student engagement through multidisciplinary perspectives, as a guide for our work of demonstrating to our students the value and interconnectedness of natural sciences, social sciences, and humanities disciplines. In order to address those outcomes, over the years we have crafted a variety of projects that students from two or more courses engage in as part of the requirements of those courses. Many of these projects included community organizations. Some of the projects and activities required funding external to our departmental budgets, especially those that involved the preparation and sharing of food and those that required travel. In many semesters, we also offered our students out-of-class experiential learning opportunities such as guest speakers, movie screenings, or farm tours.

Each semester's projects and the level of collaboration and coordination varied according to which courses were offered that particular semester. During the first years of the cluster, we created large-scale projects such as the Harvest Bounty Shared Meal and the Food and Nutrition Guidelines, which included every cluster course taught that semester. These projects required students to work in small teams (four to eight students) with students in several other classes. Highly coordinated, large-scale projects required intensive time preparation and collaboration between four to seven different faculty members (often including faculty who were not teaching a cluster course but who helped with project coordination) and our students.

Given the desire to continue meaningful projects, while recognizing the other demands of academia, in later years we created small-scale, yet still intensive, cross-course projects by partnering two or three classes and faculty members, who facilitated coordination when necessary. All projects, regardless of the scale or number of classes or students, involved a presentational component (i.e., students sharing and/or creating information to be shared with either community members or students in another class). To further simplify, we sometimes asked students to work in teams with their own classmates rather than in teams with students from other classes, thereby reducing the need for facilitated, extensive, out-of-class meetings. Most recently, we have been able to organize these coordinated small-scale projects into a showcase-style larger event held once an academic year, such as the Food Day event or the Festival of Dionysus in the Mountain South event. These projects, and other projects implemented over the past eight years, are summarized by semester in Table 2. Supplementary campus and community activities intended to enhance student experience with food, food systems, and culture are also included in Table 2.

To illustrate the difference between the multi-course large-scale projects and some more manageable small-scale projects, we offer four examples. The Food and Nutrition Guidelines Policy Project was offered three times between 2007 and 2009. In the 2008 version of this large-scale project, students studying Food Politics were organized into two committees charged with overseeing the development of guidelines for UNC Asheville; one committee focused on food guidelines and the other focused on nutrition guidelines. These students became experts in a specific food or nutrition topic and then drafted and discussed with each other a recommendation in their area of expertise. The committees then received oral or written suggestions from students in the other Food for Thought cluster classes, discussed all the guidelines as a committee,

1 During this time, UNC Asheville's Integrative Liberal Studies general education curriculum required a 9-credit hour multidisciplinary experience, called a "topical cluster," where students must complete at least one natural science course and at least one social science course from a menu of courses with content and focus loosely connected to a common theme.

TABLE 1. Student Learning Outcomes (Cited from Wingert et al. 2011)

LEARNING OUTCOME	SAMPLE ELEMENTS INCLUDED IN THE OUTCOME
Academic Attitudes	Develop interest in natural and social science fields; develop appreciation for interdisciplinary learning; develop commitment to a major
Civic Engagement	Develop appreciation of how food consumption and production is a civic issue; identify connection between science and ethics
Informed Consumer	Acquire and use knowledge to make informed food choices; acquire knowledge about the links between food production and consumption and its relationship to consumers
Interdisciplinary and Disciplinary Skills (Food and Research Literacy)	Develop research skills; develop interdisciplinary understanding of social and biological systems; understand the scientific method
Information and Communication Skills	Ability to communicate expert knowledge to a lay audience (in a range of fields); work to solve problems and present information in teams
Food Systems (Relationship between) and Social Processes	Understand the science and technology of food production and the development of food policy related to production and distribution
Food Systems (Relationship between) and Environmental Systems	Understand the impacts of food production on the environment; understand the ecological relationship between plants and humans
Food Systems (Relationship between) and Individual Health and Wellbeing	Understand where food comes from and how it impacts humans; plan and prepare a nutritionally balanced meal; understand the biology of human nutrition

and then each produced a set of proposed guidelines for our campus. Students studying Nutrition, individually or in teams of two, prepared written comments on a specific topic related to food (local, organically grown, genetic modification, waste reduction, etc.) or nutrition (achieving healthy weight, fat, sugar, salt, fiber, whole foods, etc.). Working in small groups (three to four students), students studying Food of Chemistry measured the amount of sodium in several different foods offered in the dining hall, and students studying Land Economics developed evidence-based arguments for local or organic food, specific procurement strategies, and changes to the UNC Asheville food environment. All classes presented their analyses, guidelines and recommendations to the Food Politics student committees, typically as both written and oral recommendations, for inclusion in the food guidelines. The Food Politics students then formatted the data, recommendations, and rationale from the other courses into an eighty-page document and presented their findings to campus decision-makers in December 2008. Approximately 120 people were involved (including 100 students and 20 members of the campus community including faculty, administration, and Dining Services staff), and classes met jointly at least three times over the term. Campus dining services responded by making a series of changes to their food purchasing and labeling that have largely been in place since that time. Based on their post-project reflections, Food Politics students reported that they had a sense of empowerment from participating in this ambitious effort with tangible policy change implications.

Another example of a large-scale cross-course project was the Plants, Nutrition, and Latino Food and Culture Project in Spring 2011, which involved courses from three different disciplines: Biology, Health and Wellness, and Foreign Languages. Student groups from each of the three courses were assigned a Plant of the Americas, designated by the Plants and Humans instructor as native to the Americas, and worked together to create a joint poster presentation for the UNC Asheville Undergraduate Research Symposium. Students researched each plant through the lens of their particular discipline, participated in a workshop on abstract writing, and attended a panel discussion by local food experts who use these plants in their restaurants. They then created the final posters that included botanical information (Plants and Humans students), nutritional information about the plant (Nutrition students), and a traditional recipe along with relevant cultural information (Spanish students). Additionally, students studying Nutrition completed a nutritional analysis

TABLE 2. Food for Thought Cross Class Projects and Activities

Term	Cross-Course Cluster Projects	Other Cluster Activities
Fall 2008	**Harvest Bounty Shared Meal** (Food of Chemistry, Land Economics, Nutrition, Food Politics)	Farm Tours (Cluster)
	Food and Nutrition Guidelines (Nutrition, Food Politics, Food of Chemistry, Society and Technology, Land Economics)	Seminar Series (Campus)
Spring 2009	**Poster Presentations at Undergraduate Research Symposium and North Asheville Tailgate Market** (Pathophysiology, Sociology of Gender, Nutrition, Plants and Humans)	Seminar Series (Campus)
Fall 2009	**Social Marketing Campaign Development** (Sociology of Gender, Pathophysiology) **Harvest Bounty Shared Meal** (Nutrition, Food of Chemistry, Land Economics, Spanish for Health Professionals, Freshman Seminar Course) **Food and Nutrition Guidelines** (Land Economics, Food Chemistry, Food Politics)	Seminar Series (Campus) Farm Tours (Cluster) Community Garden Tours (Cluster)
Spring 2010	None	Seminar Series (Campus) Community Garden Tours (Cluster)
Fall 2010	**Understanding Food Commodities Policy Project** (Food of Chemistry, Economics of Food, Food Politics)	Film Festival (Campus) Urban Farm Tours (Cluster) Seminar Series (Campus)
Spring 2011	**Plants, Nutrition, and Latino Food and Culture Project** (Plants and Humans, Nutrition, Elementary Spanish Fast-Track)	Seminar Series (Cluster) Film Screening (Community)
Fall 2011	**Nutrient Sources: Truth in Labeling Project** (Food of Chemistry, Nutrition) **Latino Contributions to the Food System Project** (Food Politics, Elementary Spanish II) **Gendered Health: Sugars and Artificial Sweeteners** (Sociology of Gender, Pathophysiology)	
Spring 2012	**Understanding the Economic, Botanic, and Environmental Costs and Benefits of Urban Gardening** (Economics of Food, Plants and Humans)	Seminar (Cluster) Campus Garden Tour (Cluster)
Fall 2012	**Food Day—Food Policy, Chemistry, Marketing and Food Presentations** (Sociology of Gender, Food Politics, Economics of Food, Nutrition, Food of Chemistry)	Event included speaker panel, food drive, local food tastings (Community) Seminar (Cluster)
Spring 2013	**Food Addictions Discussion** (Pathophysiology, MLA Class on Food Justice)	
Fall 2013	**Film Screening: Escape Fire Viewing and Solutions Brainstorm and Discussion** (Pathophysiology, Nutrition)	Community Garden Hours (Nutrition) Agroecology Panel (Community)
Spring 2014	**Festival of Dionysus in the Mountain South—Meal and Poster Presentations on Cultural Perspectives on Plants and Healing Traditions** (Plants and Humans, Pathophysiology, Foodways of Blue Zones) **Foodways of Nicoya, Costa Rica Meal** (Elementary Spanish II, Foodways of Blue Zones)	

of the chosen recipe, and students studying Spanish created a summary in Spanish of basic plant information shared by their peers to accompany the bilingual recipe; the posters were also shared with a YWCA Latino health program. Campus and community members were invited to learn about and taste the foods prepared, and students were evaluated on their presentations. Students from each course had to navigate group work within their own course as well as coordinate preparing the poster with groups from other courses. At the Symposium, students reported learning much more about the plant because of the collaboration with students from other disciplines.

A third example of a large-scale project involved three classes: Pathophysiology of Chronic Conditions and Illnesses, Sociology of Gender, and Health Communications. Students generated evidence-based and socially aware health recommendations for the YWCA's Diabetes Wellness and Prevention Program. This project engaged students with underserved populations in the Western North Carolina region and empowered people living with diabetes with practical information about their chronic condition. The Pathophysiology students synthesized the complex science underlying type 2 diabetes for students in the two other courses. Sociology of Gender students examined the scientific messages for evidence of bias and considered how health messages are presented in the media. Finally, Health Communications students worked to optimize the health message for people in the community who were living with diabetes and who had varied educational backgrounds. The final products from students in the Pathophysiology and Gender courses were poster presentations with various perspectives on diabetes. Health Communication students presented their social marketing campaign strategies to the YWCA Diabetes Prevention Program Coordinator orally, and in writing to the students in the other classes. Students in all three classes were highly motivated to translate their knowledge to help others better understand and prevent this very challenging disease. This unique opportunity allowed students to practice educating people from diverse backgrounds about relevant health topics. Additionally, students were offered immediate and meaningful feedback on their instruction from their audience.

An example of a small-scale cross-course project involved two courses, Economics of Food and Plants and Humans, and focused on the topic of economic and environmental sustainability of campus food production. Students studying biology (Plants and Humans) were assigned vegetable crops to grow in the campus organic garden. Each student wrote a research paper that explored the tradeoffs of some aspect of organic food production (e.g., heirloom vs. hybrid seeds, sustainable methods to amend the soil, or the tradeoffs of land-extensive vs. land-intensive cultivation methods). The students studying biology were then combined into groups of four to give presentations to the students studying economics that summarized the results from their research papers as well as the results of their garden project, including the yield of the crops they grew. This information was used by students in the Economics of Food class to finalize their analysis of the costs and benefits of campus food production and consumption. Groups of students in the Economics of Food class investigated several topics such as the time, money, and resource costs; legal and logistical issues; marketing; and revenue potential (cost savings) associated with food produced on campus and either sold on campus or used to replace food that is currently purchased. At the end of the term, students enrolled in the Economics of Food class presented the results of their analysis to the students enrolled in Plants and Humans and to campus administrators. Reflection assignments revealed that students in both classes learned a great deal not just about their assigned topic but also about the environmental and economic issues associated with campus food production. One telling feature of these reflections was that a great number of students reported learning that these issues were much more complex than they initially believed.

Even though we have interpreted our class feedback from students on cross-class projects of these types as positive, we also strove from the beginning of our collaborative teaching endeavors to objectively determine the effectiveness of this type of instruction and the student learning gains from engagement in cross-course projects. To this end, we have implemented numerous modes of assessment, which are described below.

Assessment of the Food for Thought Cluster Pedagogy

Since the inception of the Food for Thought cluster, we have worked together to assess whether cross-course projects and cluster activities impact student learning, using a variety of assessment methods (Wingert et al. 2011 and 2014). Our first assessment strategy utilized an adapted version of SENCER's Student Assessment of their Learning Gains (SALG) instrument. Since the SALG is designed for individual STEM courses, rather than for a cluster of courses across disciplines, we developed an instrument designed to measure the Food for Thought cluster learning outcomes (Table 1). Our adapted SALG was used as an entrance (start of semester) and exit (end of semester) survey instrument administered electronically using a quiz form in an internet-based course management system (Moodle).

The entrance and exit assessment surveys had sixty-one items, including eight demographic questions, one open-ended question, and fifty-two questions addressing learning outcomes and course mechanics using a five-point Likert scale. 106 students completed both surveys. The learning outcomes questions were organized into four parts: academic attitudes; civic engagement and informed consumer; interdisciplinary and disciplinary skills; and understanding of food, food systems, food choices, and social and biological relationships (Table 1). At the end of each survey students were also asked to answer the following open-ended question: "Please list three food issues that interest you most." Students were asked to list three entries in order to complete the survey.

Results from this first assessment demonstrated that our collaborative, multidisciplinary approach using cross-course projects across cluster courses led to statistically significant increases in student perceptions of their learning gains, especially related to civic engagement (effect size (Δ) = 8.0%; $p = 0.036$), food literacy (Δ = 13.8%; $p < 0.0001$), research literacy (Δ = 9.7%; $p = 0.0018$), information and communication skills (Δ = 9.2%; $p = 0.0003$), and understanding food systems (Δ = 14.2%; $p < 0.0001$). We attributed much of the positive change in students' evaluation of their learning to the cross-course projects and activities. Qualitative analysis of the open-ended questions revealed that students' interest in and engagement with food issues increased over the course of the semester, especially with respect to changing the food production and consumption systems related to the American diet (Wingert et al. 2011).

In a second assessment, we sought to extend our findings on students' perceptions of learning gains by assessing the cluster's impact on student learning, specifically regarding integrative learning across disciplines (Wingert et al. 2014). We focused on three of our student learning outcomes (Table 1) that require integrative learning: civic engagement, informed consumer, and food systems and choices. Specifically, we tested whether exposure to a focused, multidisciplinary learning environment (the Food for Thought cluster courses and activities), could result in integrative, interdisciplinary learning gains (Rhodes 2010) compared to a control group of students. In our assessment instrument, we asked students to demonstrate their achievement in integrative learning by writing statements in response to prompts about a New York Times article. The article was specifically selected because it is complex and interdisciplinary in focus. It explained the costs and benefits of the popularity of quinoa, which, although endemic to the Andes, has become popular in the U.S. due to its nutritional profile, forcing change onto the culture and economy of Bolivia. In addition, this specific topic was not discussed in any of our courses.

Using a corresponding evaluation rubric, we tested the students' evaluation of the quinoa article to determine if exposure to a focused, integrative learning environment could result in superior critical thinking skills and abilities to understand food systems, integrate learning across disciplines, and make informed decisions about food choices, markers of three of our student learning outcomes: civic engagement, informed consumer, and food systems. The instrument and rubric were based on the Critical Thinking Value Rubric created by the AAC&U (Rhodes 2010) and on studies in which critical thinking is assessed by asking students to respond to a specific article or reading. Two studies that informed our protocol prompted students to read a designated article or reading and then to evaluate an issue in written form based upon the article or reading; these responses were then evaluated using a rubric designed to assess critical thinking skills (Miller 2004; Connors 2008).

The quinoa evaluation assessment instrument was completed by 161 students in nine Food for Thought

Cluster classes and by 177 students in nine control classes. Our results showed that Food for Thought students scored significantly higher on the evaluation rubric compared to controls ($\Delta = 14.0\%$; $p = 0.0008$). Rubric scores also significantly correlated with the number of cluster courses taken (Spearman $r = 0.32$; $p = 0.04$), demonstrating the increased gain of interdisciplinary, integrative learning skills with each multidisciplinary cross-course project experience. Importantly, rubric scores did not correlate with increasing year in college, indicating that our students' learning gains were related to the learning experiences specific to the cluster and not to academic maturity (Wingert et al. 2014).

Our earlier research also showed that students perceived gains in their communication skills (Wingert et al. 2011). Our most recent assessment efforts have sought to objectively determine whether these gains are demonstrable. Student communication skills will be evaluated from cross-course project student products, such as group poster presentations and two to three minute "selfie" videos of students describing their class research. Rubrics have been designed, based on the Critical Thinking Value Rubric created by the AAC&U (Rhodes 2010), to quantitatively assess communication abilities.

Faculty Reflections on Multidisciplinary Teaching and Integrative, Interdisciplinary Learning

By making a conscious decision not to "go it alone", we (the faculty involved in this type of collaborative teaching and scholarship) have benefited in multiple ways. We have not only implemented opportunities to provide students with meaningful interdisciplinary learning (described above), but we have also added to our teaching tools, learned about each other's disciplines, delved into new areas of research, forged friendships, and have had a remarkable amount of fun along the way.

Student Learning Gains

The first reason we have chosen to not "go it alone" is that we are convinced that it makes a difference for our students. We have previously highlighted the evidence we collected that demonstrates that students have both real and perceived gains in their learning. We suggest that they benefit from seeing an integrated model of teaching and learning in front of them—we undo before their eyes illusions they (or we) may have about solutions being simple or solvable from a single perspective. Instead, they are offered the opportunity to understand disciplines' capacities to illuminate facets of a complex problem and to witness that collaboration across disciplines offers more synthetic solutions.

Teaching Gains

We also recognize a number of benefits we receive from abandoning the strategy of going it alone, and these are worth highlighting for those who might otherwise believe it is too big an effort for faculty to undertake. One particular benefit is the enhanced perspective we have on our own teaching. Pursuing the interdisciplinary learning in this collaborative manner ensures that our understanding of our effectiveness as teachers begins with us, and it has the benefit of arising organically from a collaboration of faculty who are actually doing the teaching. We have the opportunity to critically examine our strengths and weaknesses in the classroom and quickly act to build on our successes and ameliorate any deficiencies. As an example, one colleague learned from our assessment of cross-course projects that he is successful in guiding students through the steps necessary to write a good research paper, but not as successful in having them translate that research into posters and oral presentations. It is also rare for faculty to truly understand the student experience as they work through our curriculum because we generally only see them in courses in our home department. Our collaboration gives us a more nuanced understanding of the student academic experience and allows us to develop a more frank assessment of the strengths and weaknesses of students and faculty in our individual departments with respect to faculty and students in other departments.

Faculty Learning Gains

Another significant outcome of our collaborative teaching and research experience has been the opportunity to learn more from other team members about each other's disciplines, including disciplinary perspectives and pedagogical methods. We are all now more literate in each other's fields; this is, in and of itself, an outcome that is probably worth the time and energy we have put into this joint endeavor.

Faculty Scholarship Gains

We have also gained from the unique opportunity to participate in the intersection of the scholarship of teaching and learning with scholarship in our disciplines. It is more likely, however, that disciplinary scholarship and the scholarship of teaching and learning (SoTL) will coincide for the social scientists than for our colleagues in the natural sciences and humanities. That is true simply because the scholarship that social scientists pursue in their discipline bears more similarity to our scholarship of teaching than that pursued by natural scientists and faculty in the humanities. We are all teachers, so one can argue that none of us should feel conflicted as we consider undertaking pedagogical research, but it may be that someone whose research training is in the natural sciences or the humanities would need to work harder to absorb and integrate the pertinent literature, and would need more assistance in study design, analysis, and interpretation of results than would a social scientist who regularly uses these methods in their disciplinary research. Moreover, although the scholarship of teaching and learning is a project shared by scholars from all disciplines, both explicit and implicit norms about how to conduct SoTL research come primarily from the social sciences. As a team, we have become stronger in our understanding of strategies for navigating those norms. From these opportunities to learn from each other, we have all benefited both individually and collectively from the sharing of our disciplinary research expertise. It has also been a real pleasure to implement curricular ideas and write collaboratively on a topic of shared interest—innovative ways to promote student learning—and to model integrated learning for our students.

Conclusions

In the face of many competing pressures on our time and the fact that our general education curriculum is in a state of flux, we as professors must continuously reaffirm our commitment to our work together and seek recognition and support from our university to continue these efforts. We have developed both a meaningful multidisciplinary collaboration and, indeed, friendships over these years and do not wish to see this partnership dissolve. Although we risk overworking ourselves if we do not locate efficiencies in our work, we also fear that our productivity and success as teachers and researchers will decline unless we find a way to adapt to the changing needs of society, the changing learning styles of students, and a changing curriculum.

Even at a small school, it is rare to build a collaboration across departments and divisions that allows faculty to develop trust and empathy across the university. Because we have worked closely together we have come to understand each other's unique teaching and research environments and to break down barriers to communication across disciplines. Information gleaned from the experiences of these faculty members allows us to more effectively advocate for a work environment that is more humane and equitable.

We are engaged faculty—engaged in meaningful lines of inquiry with students both in our class and our colleagues' classes, engaged with the discipline of our own training as well as the disciplines of our colleagues, and directly engaged with each other. Perhaps equally important, however, is the shared recognition of our own disciplinary and individual limitations that comes from this engagement. The economist among us will never teach a chemistry or nutrition class, just as the biologist among us will not teach a sociology class. Knowledge of chemistry, economics, or Spanish alone will not be sufficient to solve the world's problems. While we (and our students) are now more able to speak each other's language and recognize our own discipline's strengths in contributing to solutions, we also recognize that the strongest teams, those teams needed to solve the world's most complex problems, are composed of individuals with exceptional disciplinary strength.

In a recent essay regarding AAC&U initiatives for integrative learning, Ann Ferren and her co-authors argue that

> Developing faculty's capacity for leadership in integrative learning, then, is not just about working with other faculty for institutional change, but also demonstrating for students what this form of leadership looks like: adaptive, collaborative, inquisitive, reflective, and boundary-crossing.

> The process of implementing integrative learning on a campus becomes a teaching tool, a means of modeling for students how to engage thoughtfully and actively in their communities toward a common purpose (Ferren et al. 2014/2015, 6).

Our experience on our campus reflects this spirit, and we concur with their conclusion that providing a model of a dynamic, functional, multidisciplinary team demonstrates to our students that no one person faces the burden of solving the problems associated with food insecurity or climate change. Indeed, choosing not to "go it alone" models engaged citizenship for our students, other faculty, and ourselves. Assessments of our multidisciplinary model provide evidence for student gains in perceptions of integrative learning and accomplishment of our goal to develop more informed citizens with multifaceted perspectives on complex civic issues. The context we provide for our students through our cross-course projects and meaningful cross-disciplinary action is exactly what is needed for promoting citizen science.

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PROJECT REPORT

Women in STEM: A Civic Issue with an Interdisciplinary Approach

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Abstract

Fewer women major in STEM than in liberal arts and social sciences. How do family background and cultural issues impact upon and help shape students' career choices and majors? Using a civic engagement approach, our transdepartmental collaboration (Mathematics, Natural Sciences, and Liberal Arts) in a community college allowed 80 students to become aware of the invisibility of women in STEM. This paper discusses the outcomes of this collaboration in terms of understanding family and cultural influences on students' career choices and motivation to major in STEM, while raising the issue of women's absence in STEM. The data supporting the research are based on conclusions drawn from analyzing students' responses to surveys and contributions to class discussions, as well as homework and writing assignments. We also present a sample of student work in an effort to assess whether the instructional objectives of our interdisciplinary civic collaboration were met.

Introduction

Despite efforts to increase the representation of women in STEM fields, the gender gap in fields such as physics and engineering still persists (American Association of University Women 1998; Brickhouse 2001; Brotman and Moore, 2008). This gap is observed in both undergraduate education and in the workplace (Brickhouse 2001).

The need to recruit a more diverse workforce in the STEM fields dates back to the Sputnik crisis and America's response to the perceived technological disparity between the U.S. and rival nations in the 1950s. Today a serious lack of workers in STEM areas is exacerbated by the underrepresentation of women entering such fields. Increasing participation in STEM areas will invigorate society's efforts to innovate and design solutions for complex technological problems in the future. Clearly, ignoring a whole cohort of potential STEM workers when there is a natural shortage of people in the field does not alleviate the problem. Furthermore, increased female participation in STEM fields may yield a more equitable society.

Within this context, the current paper involves a transdepartmental collaboration in a Community College setting. Three professors from different departments conducted action research to investigate the question of why there is a paucity of women in STEM- related fields. Data to investigate the student perspective were collected from multiple sources; surveys, assignments and class discussions, in order to strengthen the reliability of the data. The data were analyzed in order to understand the student perspective concerning the research question and to devise theories or approaches to address the problem. Throughout the project period, regular interaction and discussion among the three faculty members provided scope for reflective practices and for the refinement and improvement of subsequent stages of the project.

Contextualization, Civic Engagement, and Women in STEM: Literature Review

There is a significant body of literature focused on enhancing student interest in the STEM fields, as well as addressing the underrepresentation of women in several areas of STEM. For instance, the incorporation of real-world issues into mathematics classes has proven to be successful and meaningful for students, as is illustrated by the example of Roosevelt University, where González-Arevalo and Pivarski (2013) demonstrated the strong validity of integrating real-life, everyday connections as well as civic issues into semester-long class projects for an advanced Calculus II course. They found that students appreciated gaining an understanding of civic connections, so that they could view math not as an isolated subject, but as one that can be exploited to acquire deeper insights into real-world issues, such as the spread of HIV/Aids, levels of Greenhouse Gas emissions, wealth distribution, and population growth. The incorporation of SENCER principles (Science Education for New Civic Engagements and Responsibilities) into the course allowed students to critically explore key civic issues of local, national, and global concern from a multidisciplinary perspective.

The underrepresentation of women in the STEM sector has become a major civic issue at many hierarchical levels, including government and educational establishments (Report to the President 2010). For example, the Obama administration recently established an Educate to Innovate (2013) enterprise, comprising a partnership between the public and private sector and committed to broadening the participation of underrepresented groups in the STEM fields, particularly women and minorities, to enhance the diversity of the talent pool in this area (U.S. Executive Office of the President 2013). From the academic perspective, several studies have been conducted to explore the paucity of women and other minorities in the STEM fields, the reasons for such gender discrimination, and the obstacles women face, in order to promote strategies to overcome the diagnosed impediments. A recent study has shown that gender biases exist in science, particularly in academia. Science faculty from research universities, regardless of their gender, were found to exhibit unintentional biases towards male students (Moss-Racusin et al. 2012). This may stem from cultural stereotypes (Devine 1989).

In the 1980s and the 1990s, many scholars brought to light feminist pedagogies and feminist epistemologies (Hekman 1990; Keller 1985; Martin 1991; Pagano 1998). These pedagogies had a direct impact on course curricula and in the teaching of biology, chemistry, and physics (Barad 1995; Barton 1997; Rosser 1986; Whatley 1985). It is important to note that different majors provide different cultural environments. For instance, the humanities field is characterized by discussions and questions in classes, whereas science classes are dominated by a culture of acquiring specific skills to solve problems (Knight et al. 2011).

When looking for the roots of the underrepresentation of women in certain STEM fields, such as physics and engineering, several angles have been examined. Catsambis (1995) explored the achievement gap and science attitudes and achievements of a multi-ethnic sample of eighth grade students and found that girls' achievements were at equal levels compared to the boys, but that they had more negative attitudes towards science. Miller et al. (2006) examined gender differences in students' perceptions about science among high-school students and found that girls liked biology and health-oriented fields. However, girls often perceived science in general as uninteresting. Furthermore, the underrepresentation of women in some undergraduate STEM fields can lead to feelings of isolation and to lower self-esteem compared to the males (Seymour 1995).

Two of the authors of the current article are faculty in STEM fields where women are underrepresented. A project to understand the gender perceptions of their students came to light when they were approached by a faculty member from the Education and Language Acquisition (ELA) department, who teaches a liberal arts capstone course.

The authors' focus is on the perceptions of gender inequalities in the science and technology areas—as related to the attitudes, feelings, and behaviors that a given culture associates with a person's biological sex—from the viewpoint of students at LaGuardia Community College. We also explore student perspectives on whether they believe that such gender inequality barriers will impede their development in specific sectors of STEM.

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LaGuardia's Mathematics, Engineering and Computer Science (MEC) department has extensively invested in contextualizing mathematics using civic engagement. In this connection, MEC faculty initiated Project Quantum Leap (PQL) as an evolution of the SENCER approach, in order to teach math topics within the context of pertinent civic issues to students in remedial and entry-level mathematics classes in a municipal two-year community college (Betne 2010). This project has yielded many faculty-developed projects during its three-year funded period, including those from a cohort of non-math faculty participants. Although not all the remedial and introductory math courses in which PQL was implemented were impacted equally, the overall outcomes showed positive effects on students' critical literacy skills and quantitative reasoning. As an illustration, the MEC faculty involved infusing an introductory college algebra course with PQL projects (Jaafar 2012). These projects focused on topics of civic relevance pertaining to the environment, health, and finance in order to enhance student engagement with the course material and allow students the opportunity to gain deeper insights into critical real-world issues by applying quantitative mathematical reasoning and interpretation. Student feedback from qualitative surveys was found to be overall very positive. For example, in a project related to debt and student loans, most participants said that their understanding of debt, interest rates, and repayments had improved considerably through participation in this work (Jaafar 2012).

"SENCERizing mathematics" is not unique to the PQL projects detailed above, which have been integrated into remedial and introductory mathematics classes. For advanced mathematics, González-Arevalo and Pivarski (2013) implemented semester-long projects in capstone Calculus 2 classes that yielded many diverse student research projects. Kasi Jackson and Caldwell (2011) applied feminist pedagogies (Hekman 1990; Keller 1985; Martin 1991; Pagano 1998) to the non-science-major introductory Biology 101 classroom, but in a limited manner. The aim behind the work was to integrate scientific knowledge with topics of civic importance so that students could improve their skills in applying science concepts to real-world issues that they are familiar with from everyday life. In assignments, students were asked to identify differences between science writing and the popular reporting of science, evaluate the content of a scientific news article, and discuss the flow of information between scientists and the media. From conducting surveys, the authors observed improved student confidence in the application of their scientific knowledge to social issues and enhanced interest in the course topics, although there appeared to be little change in students' desire to take more science courses (Kasi Jackson and Caldwell 2011).

Inspired by the successes of these "SENCERized" STEM-based courses, the three faculty from MEC, Natural Sciences (NS), and ELA teamed to create assignments about a non-traditional civic issue related to the underrepresentation of women in STEM. Gender equalities and the gender gap are current and critical societal concerns (Educate to Innovate 2013; Report to the President 2010), and, as discussed in the Introduction, the paucity of women in the STEM sector has increased significantly in recent years in terms of education, degrees earned, and employment in the STEM sector (De Welde et al. 2007; NSF 2012a; NSF 2012b). With regard to employment, women are outnumbered in STEM fields in industry, business, and government, although, interestingly, in institutions with lower salaries and status, such as K-12 schools and two-year community colleges, there are often more women than men in the majority of STEM areas

(De Welde et al. 2007). A number of reasons have been proposed for the dearth of women in STEM: lack of role models and encouragement, cultural bias and discrimination, poor salaries and status, and the balancing of work-life issues (De Welde et al. 2007; Pollack 2013). Hence, the issue of women's underrepresentation in STEM must be tackled from multiple perspectives and angles. We decided to explore women in STEM as a civic issue from diverse perspectives using a contextualized, student-focused, connected-learning, SENCER-based approach.

The Participants

The students who participated in the study come from diverse backgrounds and have attained different levels of academic skills through their distinct academic and social experiences. Eighty students participated in the study. Fifty-six of these students were taking either a remedial mathematics or an introductory college algebra course, and the remaining twenty-four students were enrolled in the LIB200 capstone course. The students in the mathematics classes were in the early stages of their journey at LaGuardia, whereas students in LIB200 were close to graduation.

The capstone course was fully dedicated to discussing women's issues from an anthropological perspective. It focused on women and the sciences, and students were assigned articles and data on women's involvement or lack of involvement in the sciences and then asked to write research papers on this key issue. MEC and NS faculty participants provided some of the supporting data and articles pertaining to the theme. They also visited the LIB200 class twice separately and took charge of the discussion of one of the master readings. The NS faculty member supervised two research papers in LIB200 on two famous figures in the sciences.

Students in the two targeted mathematics courses were also assigned reading and writing material, but to a lesser extent. In addition, they were assigned mathematical content that was included in the syllabus. (The details of the materials are described in the section "Infusing Remedial Mathematics Topics with Women in STEM" and in Appendices C and D). Surveys were also conducted in the two mathematics and LIB200 classes in order to explore the perspectives, ideas, and understanding of students related to the paucity of women in the STEM field.

Our purpose is to shed light on how, through this unique transdepartmental collaboration, we integrated civic and educational principles to our course content. The paper discusses the outcomes of this collaboration in terms of how to (1) better understand the process through which our students' major and career choices are influenced by their family background and cultural biases; (2) strengthen the motivation of students, particularly women, to major in STEM; and (3) raise awareness about women's absence from the STEM field. The data supporting our research are based on conclusions drawn from analyzing students' responses to surveys conducted in the two mathematics classes and in LIB200. We also analyzed the content of a sample of student work from specific assignments in an effort to assess whether the instructional objectives of our interdisciplinary civic collaboration were met.

Methodology

In order to address the civic and interdisciplinary aspects of women in the STEM fields, several methodologies were employed, with a focus on pedagogical approaches to engage students. We combined content and thematic analysis to examine students' work and identify common patterns in students' responses to both the surveys and assignments (Savin-Baden and Howell Major 2013). First, various student surveys were conducted. A demographic survey was administered that helped us better understand the diverse backgrounds of the students. A subsequent questionnaire survey focused on other key aspects, such as the reasons for students' major and career choices and the importance of women in STEM (Appendix E). The development of these surveys was based on discussions that took place in the LIB200 and mathematics classes as well as the students' responses to assigned readings. We have not used any internal method of validation of the surveys. The research was built into the LIB200 assignments: by signing up for the course, students agreed to engage in the readings about Women in STEM and participate in the two surveys. Within this framework, the authors believed it was not necessary to estimate the percentage of students responding or to test for biases in the response frequency. Both surveys were administered to all students enrolled in the liberal arts capstone course and in the remedial and college-level mathematics courses.

Secondly, several assignments were designed in which students were given specific reading materials and relevant data as well as sets of guided questions. Using these elements, students were then asked to write appropriate essays based on the contextualized issues under consideration in this research. By "appropriate," we mean essays relevant to the topic of women in STEM, using the concepts of gender inequalities and biases and fulfilling the requirements of a capstone course. The final appropriate aspect of the essays is a result of a scaffolding approach that enables students to gradually grasp the course concepts and write a relevant final research paper, having worked through both low stakes and high stakes assignments and using ePortfolio to document their progress.

The issue of women in STEM has not previously been tackled from such an interdisciplinary and civic angle. As stated in previous work, a true interdisciplinary study involves a synthesis of at least two different disciplines or fields (Dykes et al. 2008; Lattuca 2001; Wall and Shankar 2008). The issue of women in STEM has typically been explored only from the perspective of students majoring in STEM. Our research is unique in that we are attempting to assess the benefits of a collaborative multidisciplinary approach to bring awareness to the issue of women in STEM, in the context of a liberal arts capstone course as well as in remedial and introductory mathematics courses for a predominantly non-STEM-major student population.

As we will show, each of these classes addresses in its unique way the civic issue of women in STEM using different assignments and methods. The goal of the research was to raise the awareness of all students in the classes about the underrepresentation of women in some STEM fields, rather than to target the women specifically. In this respect, the readings and discussion topics were enriched by the contrasting and diverse views of the whole group of students in the classes. We measured the impact of such an approach by the involvement of students in the class discussions and by their response or lack of response to the concerns of female students that were raised by their increased awareness of the women in STEM issue.

LIB200: Reflection on Cultural Impediments to Recruiting in STEM

The Liberal Arts Seminar explores aspects of the relationship between humanism and science and technology, and draws on texts from the humanities, arts, social sciences, and sciences. Students are required to reflect on the responsibilities of citizenship in a diverse society. The course is designated as writing intensive and, as a capstone, it offers a culminating experience for students' education at this community college.

LIB200 challenges students to demonstrate competencies in two areas: Critical Literacy requires students to understand and think about the world around them and encourages them to investigate and interrogate societal institutions and issues; Oral Communication comprises interpretation, composition, and presentation of information, ideas, and values through verbal communication. The particular LIB200 section that contributed to this research was fully dedicated to women and gender issues. The principal aim of this section was to help students acquire an awareness and a deep understanding of gender biases, and to encourage them to question and apply critical thinking to culturally constructed gender categories. The concepts studied in the course allowed students to further elaborate on the obstacles women face when they desire to enter and succeed in the STEM domain.

In terms of course content, the section analyzed theoretical literature on gender and explored various perspectives concerning women's lives from a cross-cultural standpoint that requires a multicultural approach. The multicultural aspect helped students to understand, accept, and value the cultural differences between groups, "with the ultimate goal of reaping the benefits of diversity" (Burn 2010, 8). Furthermore, relevant examples were drawn from a variety of different contexts and disciplines that are related to gender issues. For instance, the course stressed the main differences and commonalities of women cross-culturally. In this context, the Oral Communication component comprising discussions on women in STEM fits into the course unit designated as

"Women and Work." This unit covered issues related to cultural and social impediments to women's recruitment and promotion (such as the gender pay gap, the glass ceiling, etc.) as well as cultural factors that hinder women's involvement in educational and professional fields perceived as being male dominated. The social constraints in selecting a major and a job were also debated.

The interdepartmental collaboration for this project resulted in several assignments designed by the MEC and NS faculty and conducted with the LIB200 students. This collaboration did not involve team-teaching. The LIB200 instructor provided the platform for this collaboration because her class was well suited to the implementation of the research project. Although the LIB200 course elaborates extensively on gender-expansiveness (Understanding Gender 2015) and on the diversity of gender experiences across cultures, this collaborative project was designed to reflect the full spectrum of gender definition.

The collaboration encompassed the three disciplines represented by the faculty involved: the math and natural sciences instructors provided suggestions for reading material for the LIB200 students, which formed the basis for the class assignments, and also supervised the class discussions on this material. In addition, the natural sciences instructor supervised the research papers of two students enrolled in LIB200. The LIB200 instructor contributed to elaborating, supervising, and analyzing the questionnaire survey administered to the LIB200 students.

In the readings assigned for the class, critical references were made to gender inequalities, social construction of gender roles, family expectations, and social impediments in order to help explain the paucity of women in STEM. The assignments focused on (1) the general context of women and science, and (2) the life and contributions of specific women in the scientific arena. As stated earlier, the data for this research project were collected from the questionnaire survey (Appendix E), students' assignments based on the readings, and class discussions. Most of the emerging themes came from class discussions, which helped in the generation and refinement of the questionnaires. Time restrictions did not allow for any class observations or focus groups to further explore the themes. Our approach is based upon action research in that it involved selecting a focus, clarifying theories, identifying research questions, collecting and analyzing data, reporting results, and taking informed action by suggesting some measures (Kayaoglu 2015).

The questionnaire survey results are reported in "Survey Results & Assessment" below. Here we address one of the important issues for this research project: the lack of awareness regarding the presence of women in the sciences. For instance, to the question: "Could you mention the name of a female scientist?" only three students taking the mathematics classes and three students in LIB200 were able to provide an answer. In reaction to this lack of knowledge of female scientists, the NS professor designed an assignment for the LIB200 class that involved writing an essay dedicated to the contributions and life of a specific woman in science. The main aim of this assignment was for the students to explore the scientific career and accomplishments of the chosen woman and, importantly, to consider and acquire insights into the background, life, and culture of the woman, including any gender-related barriers and difficulties she may have experienced.

Further details of the assignments are given below and in the Appendices. Table 1 summarizes the different courses where the assignments in the Appendices were given.

Women and Science

TABLE 1. The Assignments in the Appendix. The X indicates the course in which the assignment was given.

	Appendix A	Appendix B	Appendix C	Appendix D
Remedial Mathematics	X		X	
College Algebra	X			X
LIB200	X	X		

This assignment was devised by the MEC faculty member.

Learning Goals: To understand the issues and factors related to the underrepresentation of women in STEM fields, to relate these issues to ones' personal circumstances and background.

Approach: Students were required to read an article entitled: "Why Are There Still So Few Women in Science?" (Pollack 2013). They were then asked to write a one-page essay based on the following questions:

1. Given your own culture, to what extent do you see the article's title statement applicable to you?
2. Suggest new ways of including women in the field of science. Provide explanations for your suggestions.

In a subsequent LIB200 class , the NS faculty led a discussion of students' opinions on the issues raised in the article. See Appendix A for more details of the assignment and samples of student output. This assignment was also completed by the students in the two mathematics classes. The MEC faculty member also introduced several other assignments that focused on more quantitative aspects of women in STEM. Some of these assignments were targeted for the remedial mathematics students, others for the college algebra group. We describe the assignments within the relevant course context below.

Specific Woman in Science

This assignment was devised by the NS faculty member.

Learning Goals: To familiarize students with the contributions of a specific woman to her scientific field, to expose students to the social issues and obstacles the woman faced at the time, to consider whether the same obstacles still exist today.

Approach: Students were asked to write a Research Paper of approximately 800–1200 words based on the contributions and accomplishments of a specific woman in science. This work exposed students to the scientific work and discoveries of the chosen woman, as well as to the social issues and obstacles the woman faced. The research paper also represented an opportunity for students to explore an area of their own academic or professional interest. See Appendix B for more details of the assignment and samples of the output of the two LIB200 students who worked on this assignment.

Infusing Remedial Mathematics: Topics with Women in STEM

At LaGuardia Community College, many students attend college part-time, have children and full-time jobs, and are often placed in remedial (also known as developmental) mathematics classes. In any given semester, approximately 7000 students enroll in a mathematics class, with forty-one percent of enrollees taking remedial mathematics. The majority of the students in developmental mathematics had negative experiences in previous mathematics classes, which has likely contributed to a low level of self-confidence, poor motivation, and/or high anxiety towards the subject (Hammerman and Goldberg 2003). Teaching remedial mathematics using a contextualized approach that invokes real-life problems in the mathematics setting can help the students engage with the subject and enhance their critical literacy skills.

The specific assignment designed by the MEC faculty member for this collaborative project is detailed below.

Learning Goals: To explain the concepts of ratio and percent using a civic issue as the contextualized medium, to master conversion from ratio to percent, to understand the meaning of a percent. The assignment reflects the interdisciplinary approach adopted in this project in that it draws its content from a gender-focused perspective. If it were not for this collaborative work, the instructor would have used examples stemming from a variety of fields (political, economic, biological…), all equally relevant to students.

Approach: This assignment comprised both in-class and out-of-class activities. The in-class activity involved students working in groups of three or four. In teaching ratios and proportions, data were used that were provided by the National Science Foundation and pertained to the employment status and median salary of 2008 and 2009 science, engineering, and health doctoral degree recipients, in terms of broad field of doctorate and sex (NSF 2010a). First, students were required to look at the table and explain the meaning of the data. Students were then required to answer several questions about ratios of males to females in the biological sciences and in the mathematical sciences. In this respect, they needed to critically interpret ratios in context. Appendix C details the assignment.

The students were also provided with a second table that represented the number of Science and Engineering (S&E) doctoral degrees by sex and by selected country (NSF 2010c). Using these data, they were asked to identify their own country of origin in the table in order to find the percent of females in S&E fields and in Non-S&E fields. They were also required to choose another country, and again find the percent of females in S&E fields and in Non-S&E fields. Finally they were asked to compare and speculate on the reasons for those percentages and any observed differences.

LaGuardia's students hail from over 150 countries. To bring a "taste of home" to the assignments, it was important for our students to learn about the status of women in science in their country of origin and compare it with the United States. Native U.S. citizens were asked to consider a country of their choosing.

The out-of-class activity comprised two components. First, students were asked to write a one-page essay explaining their own career choice, and whether it is in a STEM or non-STEM field. They were also asked to relate data from the tables discussed in class to their career choice and to consider whether the underrepresentation of women in science impacts on the societal status of women. For the second component, students were assigned to read an article entitled "Why the Status of Women in STEM Fields Needs to Change" (Thomas 2013). The article not only describes why there are few women pursuing STEM fields but also argues why the status quo needs to change. Students were asked to write a one-page essay revolving around the following statement in the article: "As a culture, we don't particularly encourage girls to play with mechanical objects which can develop both comfort and interest." They were required to critically consider whether the statement is applicable to them and to suggest new strategies for enhancing the participation of women in the sciences. The same idea was also implemented in a college algebra class, with different learning goals. The reading assignment was the same but the essay was structured differently.

Infusing College Algebra: Topics with Women in STEM

Exploiting the real-world context of Women in STEM, this assignment was designed for an introductory college algebra class in order to improve the quantitative reasoning and critical literacy skills of the students. The specific assignment is detailed below.

Learning Goals: To understand Linear Modeling, to find and interpret the meaning of the slope.

Approach: Students were presented with a table about earned bachelor's degrees by sex and field for the years 2000–2011 (NSF 2010b). They started working on this mini-project during class time but were required to complete it on their own outside of class. Details of the project are listed in Appendix D. Several questions were assigned that required students to focus on the trends in bachelor's degrees awarded to males and females in both Psychology and Engineering. First, students were asked to calculate the percent of males who earned bachelor's degrees in Engineering in the years 2000 and 2011 and the percent of females who earned bachelor's degrees in Engineering in the same years. The aim of these questions is to show that, although the number of females earning a bachelor's degree in Engineering has increased from 12,206 to 14,656 over the eleven-year period, this represents only a twenty percent increase compared with thirty-four percent for male Engineering degree holders over the same period of time. To enhance their quantitative reasoning skills, the students were then asked to interpret the calculated percentages in the context of women in science and to identify any trends that the data revealed.

To further improve students' technological literacy, they were also required to use Excel to graph the number of males who earned bachelor's degrees in Psychology versus the year (starting in 2001) and the number of males who earned bachelor's degrees in Engineering versus the year. For both graphs, students were required to find the best linear fit, interpret the meaning of the slope, and use the model to predict future values. Similar questions were asked using the number of females who earned bachelor's degrees in Psychology versus the year, and students were asked to compare the graphs. Psychology was chosen at random from among the five most popular majors in the U.S. An equally relevant data set could have been drawn from another of the five fields (U.S. Department of Education, National Center for Education Statistics 2015).

The aim of the mini-project was to depict the contrasting trends for female and male Psychology degree holders on the one hand, and for male Psychology and male Engineering degree holders on the other hand. Students were also required to interpret the meaning of the slopes and to rationalize the trends with a critical eye in order to answer a set of questions.

In their essays based on the assignment in Appendix A, students effectively related their personal career choice with what the article stated. The essays contained on average 800 words. Students used data from the table provided by the NSF, along with quantitative information they had calculated, such as the slope, to support their argument and thereby enhance their critical literacy skills.

Survey Results and Assessment

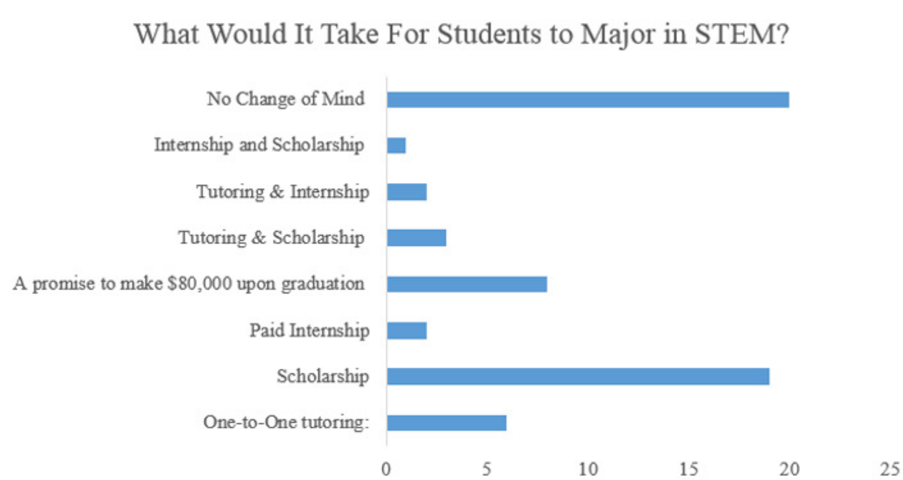
In this section, we analyze the results of the questionnaire survey detailed in Appendix E. Twenty-one students in LIB200 and forty students in the remedial and college algebra mathematics classes participated in an anonymous questionnaire survey after receiving approval from the institution's review board (IRB) to participate in this project (see Appendix E). The IRB also permitted us to conduct the qualitative research, with or without textual analysis. In terms of gender, sixty-five percent of participants in the mathematics classes and sixty-two percent in LIB200 were identified as females. In the mathematics classes thirty percent of students were found to be first-generation college-goers, compared with fifty percent for LIB200. In terms of majors, forty-three percent of participants in the mathematics classes intend to major in a STEM-related field, including nursing and health related areas, with the same percentage for LIB200.

Only thirty-six percent of all participants were aware of the status of women in the sciences prior to taking the class. This was an open-ended Yes/No answer question (see Appendix E, Question 13) and it was left to each student to individually interpret the meaning of "aware." Furthermore, only six students were able to name even one female scientist. Overall, the outcomes of the survey emphasize the value of the civic engagement aspects of this research, which serve to augment the critical understanding of the societal issue of the lack of women in the sciences and calls for both qualitative and quantitative reasoning skills. The survey also provides scope for students to reflect and critically think about STEM-related fields and why they chose their major and to evaluate their experiences, performance, and problem-solving skills at LaGuardia. It also encourages them to consider whether these skills and experiences are transferable to other subjects and to their future careers. The outcomes of some of the key survey questions are considered below.

How to encourage students to major in STEM

When trying to assess what it would take for students to major in STEM (survey Question 6), students' responses varied from a scholarship, to the promise of a

FIGURE 1. What would it take for students to major in STEM?



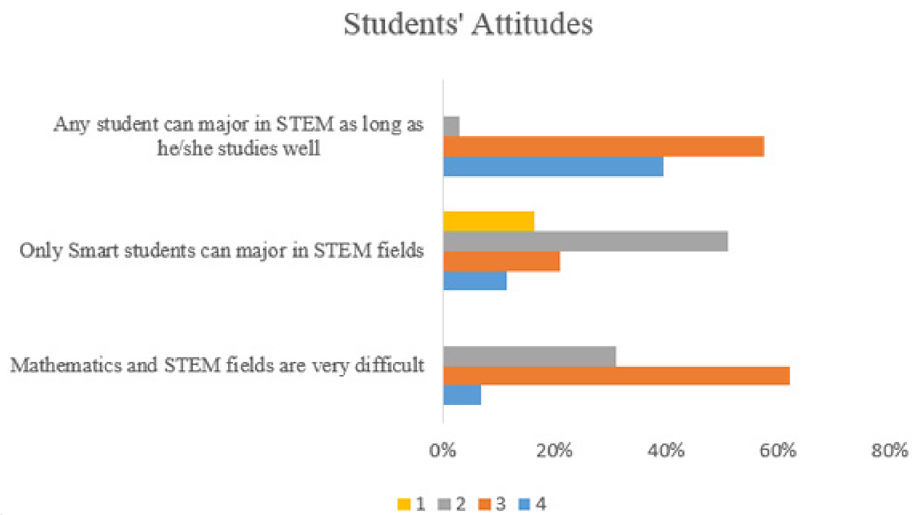
substantial living upon graduation, to the conviction that no incentive would make them change their mind (see Figure 1).

Students' attitudes

On a scale of 1 to 4, where 1 means strongly agree and 4 means strongly disagree, a majority of students (sixty-nine percent) believe that STEM-related fields are difficult majors. However, the same percentage of students do not necessarily believe that only smart students can pursue STEM fields, and almost all students agree that anyone can major in STEM fields as long as they study well (see Figure 2). This positive attitude is an indication of the maturity of the students: they all recognize that STEM fields can be difficult but that hard work can lead to success.

The next section highlights some excerpts from students' essays. Interestingly, they do not corroborate our assumption that family background plays the major role in students' career choices. Instead, there appear to be several factors that influence the major and career choices of the students.

FIGURE 2. Students attitudes towards majoring in STEM.



Who Chooses the Career Path? Excerpts from Students' Essays

To what extent do social norms, family, and gender expectation determine students' career choices? We found that our students' responses were mixed. Family background does have an impact on the career choice of some students, but for others, different factors exert the major influence, such as individual ideas and ambitions, culture (based on societal or geographical background, not just family background), and role models (or the lack of them where women in STEM are concerned). Interestingly, some students also referred to the changing of stereotypes, which are providing more opportunities for women. The males in the class also felt the influence of family and culture in their major and professional career choices but did not experience any stigma or barriers to entering the STEM field, beyond the perception of the difficulty of such subjects. A sample of students' responses is presented below.

The excerpts are taken from the LIB200 class.
One student wrote:

> My parents always told me to choose whatever career I wanted to do, they never decided for me. When I got to college I didn't know what I was going to study, but just like my parents I was thinking of doing business administration.

Another student stated:

> The culture that I am part of has brainwashed women to believing that they should just stick to the simple jobs or just play the role of a housewife. However, despite this deeming [sic] stereotype, women are challenging themselves and wanting to make changes to show that we are equally or even better qualified than men.

A student from the Caribbean Islands stated:

> ... given my own culture in the Caribbean girls are not subjected to this stigma; girls' schools allow them to select whatever they feel would give them adequate contentment in terms of career choice. Students who grow up in such settings end up not encountering difficulties in their own studies compared to those of combined schools

where both genders study together faced by discouragement.

In her research paper, a student wrote about the importance of analyzing the number of males and females in the STEM field:

> We can track inequalities cross-culturally in many different aspects; one way is to take a look at specific careers and the number of females in the field, vs. the number of males in the field. Science and engineering are fields mostly occupied by males, where typically they are respected and given gratification when deserved.

This clearly relates to the assignment conducted by students in the mathematics classes.

The excerpts below are taken from student essays in the college algebra class. Overall, the essays show that students have an appreciation of how to interpret the numerical data in the papers they were given, and they reference the lack of role models to encourage women to enter the STEM field. After each quote below, a deeper textual analysis is provided within the context of the current research question.

One student wrote

> I don't think culture influenced my career choice but rather it was inspiration and passion.... As the calculation showed, which was to find the percentage of women and men who got their bachelor's in engineering from 2000 to 2011. I found that there was and is a huge gap, for males there was a 34% increase in earned bachelor's degrees from 2000 to 2011 while for females the increase was just 20% in earned bachelor's degrees for engineering. Furthermore my calculation showed that there was a decrease of women getting their degrees in engineering while for males there was in an increase. In 2000 79.5% of males earned their bachelor's degree in engineering, while 20.5% of females got theirs. And in 2011 81.2% of males got their degrees in engineering, while 18.2% of females got theirs, this shows that more and more females are quitting the STEM field. But one of the things that surprised was the difference of earned psychology degrees for females and males; there are more females earning their bachelor's degrees in psychology than males. As the graph showed on my project, the value of slope for the females earning their bachelor's degrees is 1984, while the graph for males earning their bachelor's degrees in psychology shows a slope value of 662, that means that the increase of earned psychology degrees for females is 1984 each year while for males the increase is 662 each year. Why is it female presence in engineering is decreasing, while for psychology it is increasing?"

By "this shows that more and more females are quitting the STEM field," the student meant to say that although the number of female degree holders in some STEM fields has increased, this increase is much lower percentage-wise than the corresponding increase of male STEM degree holders. Within the framework of the research question, the data provided encourages students to interpret numbers in their context, a point discussed in class as a follow-up.

Another student related her experience to the data analyzed in a similar manner.

> Now that I am planning to transfer to a four-year school I meet with my counselor every month to discuss the career path I may choose. Just like her, she constantly recommends me to choose psychology. She never mentioned to me to consider science. She is a female who did psychology and I think she believes that it is better for me as a female to do psychology too. In the table of earned bachelor's from 2000 to 2011 it is clear that more females than males are more likely to pursue a degree in psychology. The average of females who earned bachelor's degrees in psychology per year is 1,984 while the average of males is 662.

It is clear from the essays that students mastered the use of trends and numbers in their context. In qualitative terms, most students were able to generate appropriate percentages and linear slopes from the data and interpret these values in the context of gender issues and stereotypes in the STEM field. It was also interesting to note that the female counselor did not recommend that her female student major in the sciences. What is the bias playing against both of them? This testimony is a clear indication that a lack of awareness of cultural biases against women in the sciences could not only reinforce gender stereotypes in terms of career choices and majors, but also hinder the efforts to bring more females to STEM.

The absence of female figures who could act as role models to advocate for a more female-inclusive approach was brought up by students in the college algebra class:

> The trends of fewer women entering the field of engineering has obviously impacted their status in society in several ways. If there are fewer women in the STEM world, women will have less influence and power to encourage other women in society to pursue science degrees and careers.

This remark is corroborated by a statement made by an LIB200 student, who dedicated her research paper to the iconic figure in genetic mutations, Barbara McClintock:

> For women the fields of science and engineering can be a lonely and obstacle- filled career path. We often forget the remarkable achievement of women and barely give them recognition where is due. Too often do we ignore and forget female role models.

Conclusion

As evidenced by class discussions and students' assignments and responses to surveys, the instructional objectives of our interdisciplinary civic collaboration have been thoroughly explored. Our first objective was to determine family influence on majoring in STEM and choosing a career. The surveys provided the answer that perhaps cultural biases and the lack of female role models in the sciences were stronger influences. In fact, a significant number of students argued that family had no influence on their choices. Overall, there was no single influence that stood out as the most critical in the students' decision-making process.

Although we acknowledge that students' decisions exhibit a level of agency, we believe that their perceptions reflect a lack awareness of how deeply decisions and choices are embedded in culture. This leads to our second objective: to bring awareness to women's absence in STEM. Students discussed this issue at length with the three of us. They had specific assignments on the topic, and two students dedicated their research paper to specific women scientists.

Within the action research format, the assignments and the interactions that LIB200 students had with the three professors led to deep class discussions on the detrimental factors that prevent women from fully embracing STEM majors and careers. Contributions from students ranged from cultural issues, whether things are changing now or will change in the foreseeable future, and what we can do to encourage more women into the sciences. The NS faculty member was particularly inspired by several very personal comments from students in the class regarding not only the impact on the research question from the culture of their country of origin, but also from their specific family backgrounds. He thought these students were extremely brave to air such perspectives in "public" and found the whole session very rewarding and thoroughly enjoyed the experience.

Based on such class discussions in the MEC and LIB200 classes, it appears that students lack exposure to literature about women in STEM. We therefore call for educating students in order to bring awareness to this civic issue. However, the education of students in this context goes hand in hand with educating faculty, who may also be unaware of this situation. Indeed, a student testimony shared with us how, surprisingly, a female college counselor deterred her from pursuing a major in STEM and guided her into majoring in her own field, i.e. psychology. This leads us to wonder: to what extent is higher education reinforcing gender stereotypes when it comes to career choices? These biases bear close similarity to those portrayed in Pollack's New York Times article (Pollack 2013). A relevant future study would be to explore whether infusing higher education with appropriate role models would successfully influence students' future academic and professional choices.

In order to address the above matter, we suggest that increasing exposure to women in STEM should be done across curricula by having an open discussion about the problem and by suggesting readings in freshman seminars focused on the issue. Another solution would be to provide students, especially female students, with female role models who could act as mentors. Research shows that lack of mentoring limits women's career opportunities, particularly in STEM areas. The aim of the mentoring system is to help guide the career of a junior member of the organization by sharing knowledge about how to succeed (Burn 2010). Mentoring is important in that it helps the junior employee to have access to promotions, career mobility, and better compensation (Ragins 1999). Advocacy for providing young women with personal support, job-related information, and career developmental support from their supervisors is backed by research (Bhatnagar 1988; Cianni and Romberger 1995; Noe 1988). Our collaborative research project shows that with the appropriate sensibilization to the situation and context, students took interest in the field of women in the sciences, as evidenced by class discussions, assignments, and research papers dedicated to the topic.

About the Authors

Habiba Boumlik, who holds a Ph.D. in social and cultural anthropology, also holds an M.A. in Arabic and Islamic studies and a B.A. in French as a foreign language. Her academic background and teaching experience include Arabic and French languages and literatures, cultural anthropology, women cross-culturally, Middle Eastern history, and Arab cinema.

Reem Jaafar holds a Ph.D. in theoretical physics from the CUNY Graduate School (2010). In 2010, she joined the Math, Engineering, and Computer Science Department at LaGuardia Community College as an assistant professor and was promoted to associate professor in 2013. During her tenure at LaGuardia, she has been the recipient of three grants, cofounded the Math Society, and invested in students' excellence at LaGuardia by training them to compete in regional and national mathematics competitions and by organizing STEM talks and workshops. She has coauthored thirteen papers in peer-reviewed journals and has presented her work in theoretical physics and mathematics pedagogy at over fourteen conferences.

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APPENDIX A

Write a one-page essay explaining the influence of culture on your career choice and whether you think it might have impacted your decision to major or not to major in science. In your essay, relate this statement to the statistics discussed in class and in the assignments, and explain how the presence of fewer women in science would impact the status of women in society.

Read the article: Why Are There Still So Few Women in Science?
By EILEEN POLLACK
The article can be found at:
http://www.nytimes.com/2013/10/06/magazine/why-are-there-still-so-few-women-in-science.html?pagewanted=all

Towards the end, the article states:
"As so many studies have demonstrated, success in math and the hard sciences, far from being a matter of gender, is almost entirely dependent on culture—a culture that teaches girls math isn't cool and no one will date them if they excel in physics; a culture in which professors rarely encourage their female students to continue on for advanced degrees; a culture in which success in graduate school is a matter of isolation, competition and ridiculously long hours in the lab; a culture in which female scientists are hired less frequently than men, earn less money and are allotted fewer resources."

(1) Given your own culture, to what extent do you see the statement applicable to you?

(2) Explain your position and suggest new ways of including women in the field of science.
(Write a one-page essay)

In-Class Discussion with NS Faculty
A very interesting and fascinating discussion ensued about the NY Times Women in Science article.

LIB200 Research Paper: WOMEN IN SCIENCE

The purpose of this Research Paper is to familiarize you with some of the contributions of women in science. This will expose you to the scientific work and discoveries of these women, and also to the social issues and obstacles they faced at the time. The research paper also represents an opportunity for you to explore an area of your own academic or professional interest.
Overall Format: Approximately 800–1200 words, double spaced and with a 12-pt. Times Roman font.

Report Format

The paper is in the form of a report and should include Headings and Sub-headings as described below.
The Research Paper should consist of the following sections:

(1) Title:
The title should present the name of the chosen woman and the scientific area in which she made a significant contribution. Please choose a woman you would like to write about and discuss it with your Instructor.

(2) Background information:
The background information should provide an overview of the life of the chosen woman. You could mention some details of her early life, her scientific career, and then her later life. This could also include some historical information that is relevant to the topic (e.g., a key historic moment, an important observation that led to a discovery, etc.). Here you can also establish the important contributions of the woman to her scientific field.

(3) Discussion:
This section forms the main body of the report. The Discussion should be divided into 2 parts:

i. Details of the key contributions of the chosen woman to science
This part describes the scientific area, what work the woman conducted, what her accomplishments were, and how they contributed to the field.

ii. Social issues face by the chosen woman
In this part, you should identify and discuss the social issues and barriers experienced by the woman at the time. What support did she receive? How did she overcome the obstacles? How did these experiences affect her scientific career and her life?

(4) Conclusions:
This section provides a summary of the previous sections. Discuss the legacy of the chosen woman in terms of scientific and/or social issues. Do you think women in science face similar barriers today?

Research Project Feedback

Two students in LIB200 conducted this Research Project. Their project papers are attached. They both put a great deal of effort into this assignment and produced very high quality and thoughtful papers, and it is hoped that they both enjoyed the experience.
The feedback and grades given by the NS Faculty to the two students are provided below.

Student 1
The student has chosen Woman in Science: Barbara McClintock.

This is a well-written paper. The Introduction and Background are excellent, and there is a good Discussion of the barriers overcome by Barbara McClintock, the support she received to succeed and her legacy. Student 1 also considered whether women face similar barriers today and included her own opinions on the causes of gender inequalities.

The only issues to improve the paper would have been to expand the discussion on her own opinions of gender inequalities, and more complete citation of references in the text.

Student 2
The student has chosen chosen Woman in Science: Marie Curie.

This is a very well written paper. The Introduction and Background are excellent, and there is a good Discussion of the scientific career of Marie Curie, the barriers she had to overcome and the support she received. Student 2 also considered whether women face similar barriers today in terms of the number of women in STEM fields and their salaries.

The only issues to improve the paper would be to give a little more detail of her own opinions and thoughts on the causes of gender inequalities. Also, Headings and Titles of subsections could have been used as suggested in the Guidelines document that was set (Background, Discussion, Conclusions). Finally, a list of references at the end is needed, and proper citation of them in the text as appropriate, particularly for the quotations that are used.

APPENDIX C

1. Fill out Table C1 below

Employment status by gender	Biological/ life sciences	Mathematical sciences	Physical and related sciences	Engineering
Total				
Female				
Male				
Male/Female				
Female/Total				
Percent of Females				
Percent of Males				

TABLE C1: Data taken from NSF (NSF 2010a).

2. Convert the ratio of females to the total into percent. Does your number agree with your calculation in the table?

3. From the table, what is the ratio of males to females in the biological sciences and in the mathematical sciences? Write down the ratio, and then explain the meaning of each ratio using your own words.

4. Read carefully the table http://www.nsf.gov/statistics/seind14/content/chapter-2/at02-40.pdf

a) What information does the table present?

b) Look for your country of origin in the table.

Find the percent of females in S&E fields and in non-S&E fields (S&E stands for Science & Engineering).

c) Choose another country, and find the percent of females in S&E fields and in non-S&E fields.

d) How do the two percentages compare to each other? Can you speculate why your country has the percent of women in science you found?

APPENDIX D

1. Fill out Table D1 below

Field and year	Engineering (2000)	Engineering (2011)	Psychology (2000)	Psychology (2011)
Total				
Female				
Male				

TABLE D1: Data provided by NSF (NSF 2010b).

2.

a) Calculate the percent increase in earned bachelor's degrees in Engineering for males between 2000 and 2011.

b) Calculate the percent increase in earned bachelor's degrees in Engineering for females between 2000 and 2011.

c) Which percent increase is higher?

3.

a) Calculate the percent of males who earned bachelor's degrees in Engineering in the year 2000 and percent of females who earned bachelor's degrees in Engineering in the year 2000.

b) Calculate the percent of males who earned bachelor's degrees in Engineering in the year 2011 and percent of females who earned bachelor's degrees in Engineering in the year 2011.

c) What trend do you notice between 2000 and 2011 for the female bachelor's degrees earners?

4.

a) Fill Table D2 below (be careful, start from 2001).

b) Using Excel, graph the number of males who earned bachelor's degrees in psychology versus the year (starting with year 0 in 2001 as indicated) and graph the number of males who earned bachelor's degrees in Engineering versus the year. For both graphs, find the best linear fit.

c) Write down the value of the slope for each graph, and explain what it means.

d) Which graph is increasing at a faster rate? Interpret it in terms of the slope.

e) Predict the number of male psychology and male engineering degree earners in 2020.

5.

a) Fill Table 3 (start from 2001).

b) Using Excel, graph the number of females who earned bachelor's degrees in psychology versus the year (starting with year 0 in 2001 as indicated). Find the best linear fit.

c) Write down the value of the slope for this graph and compare it with the slope of the graph that represents the number of male psychology degree earners (from question 5).

d) Which graph is increasing at a faster rate? Interpret the slope in c).

e) Predict the number of female psychology bachelor's degrees holders for the year 2020 and compare it with the expected number of male psychology bachelor's degrees holders for the year 2020.

6.

a) Fill Table D4 below.

b) Write the ratio of the number of female degree holders in engineering to the number of female degree holders in psychology for the years 2001 and 2011. Express the ratio as a percent.

c) What trend do you notice?

TABLE D2: Data provided by NSF (NSF 2010b).

Year	Earned bachelor's degrees in psychology (male)	Earned bachelor's degrees in engineering (male)
2001		
2002		
2003		
2004		
2005		
2006		
2007		
2008		
2009		
2010		
2011		

TABLE 3: Data provided by NSF (NSF 2010b).

Year	Males who earned bachelor's degrees in psychology	Females who earned bachelor's degrees in psychology
2001		
2002		
2003		
2004		
2005		
2006		
2007		
2008		
2009		
2010		
2011		

TABLE D4: Data provided by NSF (NSF 2010b).

Year	Females who earned bachelor's degrees in psychology	Females who earned bachelor's degrees in engineering
2001		
2004		
2007		
2011		

APPENDIX E

Anonymous Survey *Women in Science: Engaging Students in Liberal Arts Seminar and in Mathematics Classes*

1. I primarily Speak

i) English

ii) English and another language

iii) Another language

2. What is your gender?

i) Male

ii) Female

3. I am the first person in my immediate family to attend college

i) Yes

ii) No

4. My racial or ethnic identification is

i) Asian or Asian American

ii) Black or African American

iii) Hispanic or Latino

iv) Arab

v) White

5. My major is in a STEM field (Science, Technology, Engineering, and Mathematics)

i) Yes

ii) No

iii) Undecided

6. If you do not intend to major in STEM, what would it take to change your mind and major in STEM? Circle all that apply.

i) One-on-one tutoring

ii) Scholarship

iii) Paid internship

iv) Scholarship to attend a four-year college

v) A promise from someone that you will make $80,000 per year upon completing your bachelor's degree

iv) Other (Explain):________________________________

7. Is anyone in your family or extended family working (or graduated) in a STEM related field?

iv) Yes

v) No

8. What was the main reason why you decided attend college? (Check all that apply.)

i) My family wanted me to.

ii) I am interested in increasing my earning power by earning a college degree.

iii) I love to acquire new knowledge.

9. Did you intend to transfer to a four-year institution when you first joined LaGuardia?

i) Yes

ii) No

iii) Undecided

10. Were you good at mathematics in (circle ALL that apply):

i) Elementary school?

ii) Middle school?

iii) High school?

iv) I was never good at math.

11. What grade approximately did you earn in the last mathematics class you took at LaGuardia?

i) A

ii) B

iii) C

iv) D

v) F

12. How long did you spend studying for this course every week?

i) Less than three hours

ii) Three to six hours

iii) More than six hours

13. Prior to taking this course, were you aware of the status of women in the sciences?

i) Yes

ii) No

14. Can you name one or more famous female scientists?

____

____

____

15. Do you think that what you learned in this course helped you understand your choice of major?

i) Yes

ii) No

iii) Somewhat yes

16. Indicate the extent to which you agree with the following statements:

	Strongly Agree	Agree	Disagree	Strongly Disagree
Mathematics and STEM fields are very difficult				
Only smart students can major in STEM fields				
Any student can major in STEM as long as he/she studies well				
I intend to major in a field I like, regardless of how easy it is				
I intend to major in a field I may not like just because it is easy				
I am a self-starter and self motivated				
I manage my time well and meet deadlines				
I know where to look for answers on problems I have difficulty with				
I know when to make judgments about the soundness of information and arguments				
The faculty and staff at LaGuardia care about me				
My experience at LaGuardia helped me change the way I see myself and life				
The skills and knowledge I acquired during my class this semester might help me succeed in other courses				

17. What were the biggest challenges you encountered in this course?