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Engagement in Practice: Promoting Environmental Health Literacy to Raise Awareness of Antibiotic Resistance

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Engagement in Practice: Promoting Environmental Health Literacy to Raise Awareness of Antibiotic Resistance

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Abstract

The process of how to engage with communities (i.e., community engagement) is an important skill for engineers to acquire, and the skill is well suited to experiential learning (i.e., learning through doing). To educate engineers to perform community engagement, a module was developed and incorporated as part of three different engineering courses, namely: 1) science, technology, engineering, art, and math (STEAM) diplomacy (dual-level graduate and undergraduate, elective); 2) public health engineering (dual-level graduate and undergraduate, elective); and 3) biological principles of environmental engineering (graduate only, required course). These courses were offered at the Missouri University of Science and Technology and through Missouri Online distance education. The primary audience included students of environmental engineering as well as students of civil engineering and architectural engineering and students of nursing. The module included an overview of community engagement, gathering community information, co-identification of a problem and a solution, and testing the solution.

While many forms of community engagement often aim to unearth problems and co-design solutions in a partnership between the researcher/scholar and the community/stakeholders, in this module the process of community engagement was pre-seeded with the problem that a lack of environmental health literacy among the general public is a significant contributor to the spread of antibiotic resistance (i.e., resistance to antibiotics spreads among communities where individuals lack awareness, scientific understanding, and access to ways to prevent the spread of resistant bacteria). The pre-seeded problem was offered by the United States Department of State as part of a Diplomacy Lab exercise. Thus, students engaged with representatives of the State Department in place of direct engagement with community members. As a pre-seeded solution to this problem, the State Department requested that students develop infographics. Subsequently, as part of additional community engagement, students used these infographics to educate individual community members about antibiotic resistance. Thus, by the strictest definition of "community engagement", this module represents a variation from the true sense of "best practice". None the less, over a period of eight years, a total of 130 students have participated in a variation of community engagement by completing this module incorporated into three different courses, which were offered a total of 17 different times.

Lessons learned include: 1) although hesitant at first, many engineering students eventually recognized the benefit of community engagement to promote environmental health literacy; 2) developing infographics was a challenge for engineering students (i.e.,

specifically the creation of "graphics" was a challenge); and 3) the results of community assessment with student-designed materials were similar to the results reported in the general scientific literature suggesting that students of engineering were no worse than professional science communicators at raising awareness of antibiotic resistance.

The conclusion of this study is that a lack of environmental health literacy is a suitable problem to use when teaching the skill of community engagement among students of engineering as demonstrated through a specific case-study of raising awareness of antibiotic resistance.

Introduction

Since 1928, antibiotics have revolutionized modern medicine by contributing to the prevention of millions of deaths due to bacterial infections. Unfortunately, even as antibiotics were initially developed and distributed for wide-spread use, the emergence of bacteria resistant to specific antibiotics resulted in "superbugs" that killed people with ever greater efficiency. For the past century, an escalating "bio-warfare" has emerged with scientists developing and pharmaceutical companies producing and marketing new antibiotics (i.e., ways to kill) while bacteria responded by developing new resistance (i.e., ways to escape). Ultimately, the future looks bleak for human health as bacteria increasingly fail to respond to treatments due to antibiotic resistance; healthcare professionals have issued urgent warnings that the benefits of antibiotics enjoyed for nearly a century may be ending with a resurgence in deaths from untreatable bacterial infections [1, 2, 3].

One of the reasons for the prevalence of antibiotic resistance is the lack of antibiotic literacy among the general population. For example, some patients demand antibiotics from healthcare providers for the treatment of what are likely viral infections where antibiotics are not useful. Some patients fail to take the full course of a prescribed antibiotic, which can leave behind bacteria that are increasingly resistant to future treatment. Some patients store unused antibiotics and share these antibiotics with family and friends who are sick, which may contribute to the spread of resistance as the wrong antibiotic may be used to treat a sickness because of a lack of healthcare knowledge. Since 2015, raising awareness about the issue of antibiotic resistance has been an effort of the United Nations through the introduction of "Antimicrobial Awareness Week" activities annually during the second week of November. Recent systematic reviews, a type of literature review designed to provide evidence to inform healthcare practice, conclude that a number of hurdles exist to prevent the success of awareness raising campaigns [4].

As part of raising awareness of antibiotic resistance among the general population, the process of community engaged has been used to incorporate an understanding of the importance of environmental health literacy into three engineering courses offered at the Missouri University of Science and Technology. Details of these course have been published previously, including:

1. science, technology, engineering, art, and math (STEAM) diplomacy [5],
2. public health engineering [6], or
3. biological principles of environmental engineering [7].

The original impetus for the selection of raising awareness of antibiotic resistance was the involvement of the author in the Diplomacy Lab program offered by the United States Department of State [8]. "DipLab" provides a platform to "course source" the "wicked problems" identified by America's diplomatic corps. Students, working under the supervision of a faculty mentor and in collaboration with representatives from the Department of State, explore the full understanding of and identify solutions to problems that threaten America's national security and the security of America's allies. The rise of and global spread of antibiotic resistance represents an example of such a threat, and the Department of States suggested that the problem and the solution to the problem included an urgent need to improve environmental health literacy [9, 10].

Environmental health literacy incorporates expert knowledge and research strategies from health sciences, social sciences, and environmental sciences as part of an emerging area of study [11]. Environmental engineering is one of the professions that contribute to and benefit from improvements in environmental health literacy. Therefore, the author applied for and received an invitation to engage with the DipLab program in response to a solicitation to address the spread of antibiotic resistance [8].

This article describes the educational module developed to teach community engagement. Although most applications of community engagement often begin with an effort to co-identify a problem in collaboration with a community and to co-identify and co-own solutions in collaboration with a community, the module described in this article was pre-seeded to identify that the "problem" was that a lack of environmental health literacy among the general public is a significant contributor to the spread of antibiotic resistance. The process of "pre-seeding" with a problem as well as "pre-seeding" with a potential solution (i.e., the use of infographics to increase environmental health literacy) reflects the direction provided through the DipLab project. Over a period of eight years, a total of 130 students have participated in the process of community engagement by completing this module incorporated into three different courses, and this article summarizes the lessons learned.

Methods

<u>Course Catalog Description.</u> A module was developed and incorporated into three separate courses. The descriptions of each course are provided, below:

1. CArE 5001: Experimental Course: "Science, Technology, Engineering, Art, and Mathematic (STEAM) Diplomacy aims to excite interdisciplinary students to consider diplomatic craft and foreign policy to further professional business interests as well as to contribute to creating a more secure, democratic, and prosperous world for the benefit of the American people and the international

community. While STEAM Diplomacy is inherently global, to facilitate the introductory nature of this course, the materials will be discussed with an emphasis on American foreign policy approaches." [5, 8, 12]

2. CArE 5650: Public Health Engineering: "A comprehensive course dealing with the environmental aspects of public health; emphasis is placed upon providing a risk-based introduction to many of the biological, chemical, and radiological hazards that impact human health, particularly from anthropogenic origins. Basic epidemiological and toxicological concepts are introduced and utilized in a risk assessment framework for existing and emerging threats to human health. Risk management, through technology and policy, is introduced as a means to reduce exposure and improve clinical outcomes. When combined with risk communication, these fundamental skills serve as the basis for an introduction to the practice of environmental health as described in the Guide for Environmental Health Responsibilities and Competencies by the National Environmental Health Association." [6]
3. CArE 6601: Biological Principles of Environmental Engineering Systems: "This course covers the fundamental biological and biochemical principles involved in natural and engineered biological systems. This course builds upon concepts introduced in the sophomore-level Biological Fundamentals of Environmental Engineering. This course should be viewed as a parallel to the graduate-level Chemical Principles in Environmental Engineering, and this course should be viewed as foundational to the applications found in the graduate-level Biological Operations in Environmental Engineering Systems, as well as other courses."

<u>Course Delivery.</u> Although the content of these three courses is different, all three courses are delivered using a common pedagogical format [13]. The pedagogical approach for each of these three courses includes: a blended format; a flipped classroom; mastery learning; and a buffet of optional summative assessments used to assign a final grade. Briefly, the "blended format" includes delivery of course content via both online digital media and via face-to-face lecture. A "flipped classroom", where students are exposed to course content before participating in a formal lecture with the instructors enhances the opportunity for the use of inductive learning strategies (i.e., think-pair-share). Mastery learning allows students to self-pace as they struggle individually, and collectively, to obtain the knowledge, skills, and attitudes described in the learning objectives. And finally, a buffet approach to summative assessments – after minimum mastery has been achieved – provides an alternative approach to grade contracting where students select specific activities to complete successful as demonstrations of their understanding of the course content.

A module on community engagement to improve environmental health literacy to address the spread of antibiotic resistance was developed and integrated into each of these three courses.

<u>Module current details and historical development.</u> The content for community engagement covered in this module comes from the practical experience of the author developing a Caribbean-wide project entitled, COAST – the Caribbean Ocean and

Aquaculture Sustainability faciliTy [14]. In the COAST project, the author worked on behalf of the United States Department of State to coordinate a Caribbean basin-wide diplomatic project involving a variety of government and non-government actors as well as individual local citizens. Thus, the author has substantial unique personal experience in science diplomacy that serves to underpin the community-engagement activity undertaken as part of this module. The current version of the module incorporated into each course is provided in Appendix A, and students are introduced to community engaged scholarship through a critical read of an article published by the author describing the creation of COAST [14]. As described in detail in Appendix A, community engagement includes identifying and recruiting stakeholders who help to craft a common problem statement, brainstorming shared possible solutions, and then select and implementation an agreed solution with shared responsibility for success and dissemination.

In the case of the historical development of the module presented in Appendix A, the author responded to a call for proposals issued by the United States Department of State soliciting universities to support "over-the-horizon" research that benefits America's diplomatic interests. Appendix B includes the original request for proposals from the Statement Department, and Appendix C includes the original proposal by the author.

Unlike the ideal approach to community engagement – where stakeholder identification is inclusive and comprehensive – during the historical development of this module the "stakeholders" were limited to various individuals identified by the State Department. Students engaged in research under the direction of the author, and then shared regular reports with the State Department who provided feedback on progress and suggestions for future work. Appendix D includes a representative presentation created by students and used by students as part of a briefing to the State Department.

In part, based upon the input from the students working with the author, the United States Department of State issued an additional request for proposals as part of Diplomacy Lab. This additional request is provided in Appendix E and the proposal submitted by the author is included in Appendix F.

This second phase of the overall project progressed from problem identification to implementation of a solution; in this case the development of an infographic and the subsequent use of the infographic by individual students to raise awareness of antibiotic resistance in the public.

To measure the effectiveness of infographics to assess the success of awareness raising, a survey instrument was development (Appendix G), and students conducted surveys of the public. Individual members of the public identifying as non-citizens, were shown the infographic previously developed by the World Health Organization (Appendix H); whereas individual members of the public identifying as citizens of the United States, were shown the infographic developed by the engineering students (Appendix I).

Overall results of the implementation (i.e., the recorded results of members of the public responding to the survey) were analyzed by students, and the results were presented in the form of written reports (i.e., Appendix J) submitted to the State Department who provided feedback and asked further questions of the students. In this way, the original community stakeholders – the United States Department of State – were aware of and involved with the implementation of efforts by students to raise awareness of antibiotic resistance. These reports also served as a means of disseminating the results the students learned from the performance of the surveys.

During the 2022 Autumn semester, students were offered an opportunity to re-consider the format and content of the infographic previously designed by students. Appendix J presents the "updated" infographic generated in a graduate level microbiology course.

Assessment of student satisfaction.
At the end of every semester, the Missouri University of Science and Technology offers students an opportunity to participate in an online, anonymous assessment of student satisfaction where students report on the effectiveness of the instructor, the value of the course content, and other metrics of teaching effectiveness. As part of these assessments, students are offered an opportunity to provide free responses to open-ended questions on the subject of "what is a strength?", "what is a weakness?", and "what should be improved?" for both the instructor as well as the course. Representative responses relevant to the module on antibiotic resistance are provided in Appendix K.

Human subjects. Exemption for this education activity was provided by the Institutional Review Board (IRB) at the Missouri University of Science and Technology.

Results

The author initially used the Autumn 2015 offering of CArE 6601 Biological Principles to work with 5 graduate students to conduct preliminary research, author positions papers, and share feedback with the State Department as part of a Diplomacy Lab project entitled, "Preventing a future without antibiotics: a social science research agenda," (Appendix B). The primary goal, as identified by the State Department as the sole stakeholder with whom the author and students worked, was, "developing a set of critical areas for future investigation." As part of Diplomacy Lab, this project was incorporated into multiple courses (see Table 1). For example, in 2015 Autumn graduate students in environmental microbiology focused on the first version of a report. In 2016 Spring a mixture of undergraduate and graduate students worked together in a dual-level course on public health, and in 2016 Autumn graduate students in environmental microbiology finalized the work and presented reports to the State Department.

Appendix D is an example of the PowerPoint slides presented by students to representatives from the State Department. As documented in Appendix D, as part of identifying appropriate cognitive frameworks for understanding and raising awareness about antibiotic resistance (i.e., Appendix B), students provided a number of examples of other areas where behavior change has been tried. Students also identified that infographics historically have been an effective tool as part of "nudge economics" and other types of behavior change.

Table 1. Courses where antibiotic resistance module was offered as part of an optional, semester-long project focused on individual and group work developing an infographic as part of Diplomacy Lab.

Semester; Course	**Participating / Total Students**
2015, Autumn; CArE 6601 Biological Principles	5 / 5
2016, Spring; CArE 5650 Public Health Engineering	15 / 21
2016, Autumn; CArE 6601 Biological Principles	5 / 5
2017, Autumn; CArE 6601 Biological Principles	7 / 13
2018, Spring; CArE 5001 STEAM Diplomacy	9 / 9
2019, Spring; CArE 5001 STEAM Diplomacy	17 / 17
2019, Autumn; CArE 6601 Biological Principles	5 / 7
2020, Spring; CArE 5001 STEAM Diplomacy	9 / 9
2020, Autumn; CArE 6601 Biological Principles	*4 / 9
2022, Autumn; CArE 6601 Biological Principles	4 / 8

* Collecting community data was not possible due to restrictions due to COVID-19

The United States Department of State responded positively to this work by the students, and they created an additional Diplomacy Lab call for proposals specifically focused on messaging. The primary goal, as identified by the State Department (Appendix E) included, "creating prototype messaging tools such as videos, posters, and audio recordings." In response to this stakeholder feedback, students began a process of creating infographics as well as implementing a strategy to share these info graphics with the public as part of an awareness raising campaign. Table 2 specifically lists courses where students used the infographics developed by classmates to survey the public.

Table 2. Courses where antibiotic resistance module was offered as part of an optional, semester-long term project focused on individual effort collecting community data.

Semester; Course	**Participating / Total Students**
2018, Spring; CArE 5650 Public Health Engineering	22 / 29
2018, Autumn; CArE 6601 Biological Principles	6 / 6
2019, Spring; CArE 5650 Public Health Engineering	7 / 39
2020, Spring; CArE 5650 Public Health Engineering	4 / 52
2021, Spring; CArE 5650 Public Health Engineering	* 0 / 42
2021, Autumn; CArE 6601 Biological Principles	9 / 12
2022, Spring; CArE 5650 Public Health Engineering	2 / 61

* Collecting community data was not possible due to restrictions due to COVID-19

To determine the effectiveness of an infographic to raise awareness and educate a member of the public, a survey instrument (Appendix G) was created. Students would visit public venues – such as outside of a grocery store or at an eating establishment on campus – and invite individual members of the public to participate in an awareness raising exercise. As described in Appendix G, students would invite voluntary, anonymous participation. After collecting some basic demographic information, voluntary, anonymous public participants were asked a series of six questions; shown an infographic; and then the same six questions were repeated. This exercise allowed students to engage in community research as part of the implementation process (i.e., prior students had engaged in community research as part of understanding the problem and creating a solution).

The results collected with an infographic developed by the World Health Organization (Appendix H) and the infographic developed by students (Appendix I) were summarized at various points throughout the study by students in various courses. Appendix J presents an example of the type of summary reporting prepared by students and shared with the State Department. As described in Appendix J, the public responded positively to the infographics – in other words, correct answers to questions were a higher portion of answers after viewing the infographic as compared to before viewing the infographic. The results also suggest that individuals who do not have a college education as well as individuals who were not citizens of the United States tended to gain the most from the infographic (i.e., the results from before and after were more pronounced for these two subpopulations as compared to the overall result). Collectively, these results demonstrate that the "infographics work" and raise awareness among the public about the sources, dangers, and solutions to antibiotic resistance. As described in Table 2, these surveys have been conducted by a variety of students from three different courses. The only substantial change over the past several years has been the interruption in public engagement due to COVID-19.

In the Autumn semester of 2022, given the aftermath of COVID-19 and the proliferation of misinformation as well as poor use of antibiotics during the pandemic, graduate students in CArE 6601 Biological Principles again worked together to redesign a student-created infographic (Appendix J). The preliminary data collected by students using the infographic in Appendix J were similar to the earlier data collected by students using the infographic in Appendix I. A future publication will explore in greater depth the changes in the infographic and the results of surveys with the public.

To better understand how students perceived the value of community engagement through this module on antibiotic resistance, end of semester course evaluations were reviewed specifically to identify representative comments by students regarding this course module. Examples of the types of comments offered by students are included in Appendix K.

First, it is important to note that students were not specifically asked about this course module, but rather voluntary comments that relate to the course module were identifying during a review of the historic data. Some students found the Diplomacy Lab project to be inappropriate for a course (i.e., "… I think it is unacceptable to force students to participate…", and other students found the use of a real world example invaluable (i.e., "… this was excellent exposure to a topic that I was not overly familiar with … I really did enjoy and what I came here for, being forced to learn, use my brain and use my skills that I have developed over time.") A nearly ideal response was offered by a student in 2020 Spring offering of 5650 Public Health, where the student attributed this module – and this course – in a positive fashion (i.e., "I do not think I have had an instructor stimulate and motivate me more than Dr. Oerther has to become a better engineer … I will almost certainly remember that duty to the public I have with my profession as an engineer…").

Discussion

Community engagement is an important skill for engineers to acquire, and collaboration with other healthcare professions, such as nursing, is one practical approach [15, 16]. Ideally, engineers would learn through hands-on experience how to perform community engagement following best practices as implemented in healthcare. This should include identification and recruitment of stakeholders, who work with the researcher to identify the problem, brainstorming solutions, and select for implementation the best solution. Ultimately community engagement includes the researcher working with the community to implement, co-own, and disseminate the results of the solution.

In the current study exploring the results of a case study of a new module on antibiotic resistance, the United States Department of State served as the primary stakeholder – identifying the major problem and selecting the solution for implementation. None the less, this project provided an opportunity for students of engineering to engage in real world learning (i.e., problem-based / serving learning).

Thus, while many forms of community engagement often aim to unearth problems and co-design solutions in a partnership between the researcher/scholar and the community/stakeholders, as described in this article the problem was pre-seeded with the observation that a lack of environmental health literacy among the general public is a significant contributor to the spread of antibiotic resistance. Student research confirmed this problem and suggested that infographics would be a possible solution to raise awareness and inform the public of the importance of antibiotic resistance.

The State Department also pre-seeded the selected solution – namely developing an infographic. After creating the infographic, subsequently, as part of additional community engagement, students used these infographics to educate individual community members about antibiotic resistance. Although this module represents a variation of the strict definition of best practice in community engagement, none the less, it offered students an opportunity to learn about and engage in community centered research.

Over a period of eight years, a total of 130 students have participated in this variation of community engagement by completing this module incorporated into three different courses, which were offered a total of 17 different times. Exposure to some form of community engaged scholarship offers students of engineering an opportunity to recognize bias and expand skills to work with communities as future Professional Engineers. The Diplomacy Lab project on raising awareness to antibiotic resistance provided a useful platform to train environmental engineering students to learn about community engaged scholarship.

As noted in report presented in Appendix J, engineering students found it to be challenging to use their communication skills to create an infographic, and some students rejected the idea of being asked to work on a project with the Department of State as part of coursework (Appendix K). The results of end-of-semester assessments did show that at least some students were very pleased with the opportunity for real-world learning (Appendix K). Once the infographics were made, surveys of individuals in the public documented that infographics were useful for raising awareness and educating the public AND infographics created by engineering students were no worse as compared to infographics created by professional health organizations such as the World health Organization.

Collectively, these results point to three primary lessons learned from this work, namely:
1) although hesitant at first, many engineering students eventually recognized the benefit of community engagement to promote environmental health literacy;
2) developing infographics was a challenge for engineering students (i.e., specifically the creation of "graphics" was a challenge); and
3) the results of community assessment with student-designed materials were similar to the results reported in the general scientific literature suggesting that students of engineering were no worse than professional science communicators at raising awareness of antibiotic resistance.

Conclusion

Over a period of eight years, a total of 130 students participated in community-engagement completing a module incorporated into three different courses. Lessons learned include: 1) although hesitant at first, many engineering students eventually recognized the benefit of community-engagement to promote environmental health literacy; 2) developing infographics was a challenge for engineering students (i.e., specifically the creation of "graphics" was a challenge); and 3) the results of community assessment with student-designed materials were similar to the results reported in the general scientific literature suggesting that students of engineering were no worse than professional science communicators at raising awareness of antibiotic resistance.

The conclusion of this study is that environmental health literacy is a suitable framework to use when promoting community-engagement among engineering students as demonstrated through a specific case-study of raising awareness of antibiotic resistance.

Future efforts should include "scaling-up" this approach to include additional instructors as well as "expanding" this approach to explore additional subject matter such as the food-energy-water nexus, zero waste, and climate resilience among other topics for environmental health literacy.

References

1. R. Aminov, R"A brief history of the antibiotic era: Lessons learned and challenges for the future," *Front. Microbiol.,* vol. 1, no. 134, 2010. [Online] Available: https://doi.org/10.3389/fmicb.2010.00134.
2. S. Oerther and D.B. Oerther, "Antimicrobial resistance needs to be combated at primary levels of prevention by nurses," *Nurs. Open,* vol. 7, pp. 678-679, 2020.
3. S. Oerther and D.B. Oerther, "The ethical challenges of antimicrobial resistance for nurse practitioners," *Nurs. Open,* vol. 7, pp. 904-906, 2020.
4. H. Kosiyaporn, S. Chanvatik, T. Issaramalai, W. Kaewkhankhaeng, A. Kulthanmanusom, N. Saengruang, W. Witthayapipopsakul, S. Viriyathorn, S. Kirivan, W. Kunpeuk, R. Suphanchaimat, A. Lekagul, and V. Tangcharoensathien, "Surveys of knowledge and awareness of antibiotic use and antimicrobial resistance in general population: A systematic review," *PLoS One,* vol. 15, no. e0227973, 2020. [Online] Available: https://doi.org/10.1371/journal.pone.0227973.
5. D.B. Oerther, "Science diplomacy: Results from a three-year pilot," in *ASEE Annual Conference & Exposition, Virtual Conference, July 26-29, 2021*. [Online] Available: https://peer.asee.org/37701.
6. D.B. Oerther, "Introduction to public health for environmental engineers: Results from a three-year pilot," in *ASEE Annual Conference & Exposition, Salt Lake City, Utah, USA, June 24-27, 2018*. [Online] Available: https://doi.org/10.18260/1-2--30720.
7. D.B. Oerther, "Integrating biological principles in environmental engineering: Summary results of a three year pilot study," in *ASEE Annual Conference & Exposition, Nashville, Tennessee, USA, June 23-25, 2003.* [Online] Available: https://doi.org/10.18260/1-2--12315.
8. D.B. Oerther, "Diplomacy lab provides term-length group projects integrating policy analysis and liberal arts into the traditional engineering classroom," in *ASEE Annual Conference & Exposition, Columbus, Ohio, USA, June 25-28, 2017.* [Online] Available: https://doi.org/10.18260/1-2--28183.
9. D.B. Oerther and S. Oerther, "Advancing global public health using science-for-diplomacy," *Perspec. Public Health,* vol. 141, pp. 133-135, 2021.
10. D.B. Oerther and H. Klopper, "Improved health diplomacy is necessary for resilience after COVID-19," *J. Environ. Eng.,* vol. 147, pp. 01821003, 2021.
11. A.G. Hoover, "Chapter 1: Defining Environmental Health Literacy," in S. Finn and L.R. O'Fallon (eds), *Environmental Health Literacy*, 2019. [Online] Available: https://doi.org/10.1007/978-3-319-94108-0_1.
12. D.B. Oerther, "Science, technology, engineering, art, and math (STEAM) diplomacy: Preliminary results from an initial pilot course," in *ASEE Annual Conference & Exposition, Salt Lake City, Utah, USA, June 24-27, 2018*. [Online] Available: https://doi.org/10.18260/1-2--30952.
13. D.B. Oerther, "Experience with mastery learning in engineering courses," in *ASEE Annual Conference & Exposition, Tampa, Florida, USA, June 15-19, 2019*. [Online] Available: https://doi.org/10.18260/1-2--32788.
14. D.B. Oerther, "A case study of community engaged design: Creating parametric insurance to meet the safety needs of fisherfolk in the Caribbean," *J Environ. Eng.,* vol. 148, no. 05021008, 2022.
15. D.B. Oerther and S. Oerther, "From interprofessional to convergence: Nurses educating V-shaped professionals," *Nurs. Educ. Pract.,* vol. 53, pp. 103047, 2021.
16. D.B. Oerther and S. Oerther, "Comparing oranges versus grapes as a metaphor of the nurse+engineer," *J. Clin. Nurs.,* vol. 31, pp. e14-e15, 2022.

Appendix A. Comprehensive details of the course module. Portions of this module have been used in three different courses.

The objective of this module is to familiarize students with critical vocabulary and historical landmarks from the development of community engaged scholarship as well as to introduce students to effective use of community engaged scholarship through a series of "hands on" activities.

By the end of this module, students should:

1) be able to define community engaged scholarship
2) recognize the historical origins of action research to achieve improvements in society
3) describe – in detail – the steps involved in community engaged scholarship
4) demonstrate community engaged scholarship including the critical steps of:
    a. stakeholder identification and recruitment
    b. identifying a shared problem statement
    c. evaluating alternative solutions
    d. co-ownership of a sustainable solution
    e. implementation
    f. disseminating results and iterating the process to achieve further improvements

As part of teaching, students are directed to read and discuss D.B. Oerther, "A case study of community engaged design: Creating parametric insurance to meet the safety needs of fisherfolk in the Caribbean," *J. Environ. Eng.,* vol. 148, no. 05021008.

An excerpt from the Techniques section of this article is copied verbatim below:

> ***Techniques***
>
> <u>*Community engagement*</u>
>
> *A three-stage approach was used for community engagement (Hacker, 2013). In the first stage (i.e., identifying), the community was defined, all stakeholders were engaged, and historical and current conditions were assessed contributing to the emergence of a shared problem statement (World Bank, 2020). In the second stage (i.e., planning), all stakeholders agreed on roles and responsibilities, including theoretical frameworks and empirical approaches. In the third stage (i.e., executing), cycles of action, impact analysis, and dissemination were undertaken until successful execution solved the problem for the long-term (i.e., COAST was renewed for a third policy year in 2021/2022).*
>
> *The target community for COAST was selected initially by the United States Department of State (US DoS) as part of public diplomacy to address issues raised by some leaders from the Caribbean basin. Global multi-lateral stakeholders (i.e., World Bank) were consulted by the US DoS on the basis of expertise and past experience. Regional multi-lateral stakeholders (i.e., Caribbean Regional Fisheries Mechanism or CRFM) were invited to share leadership for the project through diplomatic engagement and on the recommendations of trusted global multi-lateral stakeholders. Individual, local fisherfolk and members of the post-catch processing industry were invited to collaborate through personal relationships as part of diplomatic engagement. Through questionnaires, internet surveys, interviews, focus-group discussions, briefings, and diplomatic engagement, stakeholders contributed to co-identifying the problem, co-planning the solution, and co-executing success.*

The creation of COAST was funded by a transfer of funds from the US DoS to a multidoor trust fund operated by the World Bank. The US DoS has not adopted the Federal Policy for the Protection of Human Subjects, also known as the "Common Rule", originally published in 1991 and most recently updated in 2017 (Federal Policy for the Protection of Human Subjects, 2017). Therefore, COAST was not subject to Institutional Review Board (IRB) approval. Rather, the principles of the World Bank Environmental and Social Framework (ESF) were followed during planning and execution of COAST (World Bank, 2017a). In addition, broader ethical considerations summarized in the literature guided the efforts to engage with communities (i.e., Mikesell et al., 2013).

Public diplomacy

As defined in the preface to a special issue on the subject of public diplomacy appearing in the Annals of the American Academy of Political and Social Science, "public diplomacy [means] an international actor's attempt to advance the ends of policy by engaging with foreign publics," (Cowan and Cull, 2008)…

Official development assistance

Foreign assistance refers to financial, material, or in-kind aid provided by a donor nation to a recipient, which is typically a low or middle-income nation (as defined by the World Bank). Historically the chief financial flow is known as "official development assistance" (ODA), which includes grants, where no repayment is required, or concessional loans, where interest rates are lower than prevailing market rates…

Bi-lateral diplomacy

In the simplest form, bilateralism is a diplomatic relationship between two individuals. As the individuals are replaced by more complex entities (i.e., families, churches, corporations, governments, etc.), the bi-lateral relationship remains between two individuals who represent each entity (i.e., the head of state from a host nation and the visiting ambassador personally representing the head of state from another nation)…

Multi-lateral diplomacy

Multi-lateral (i.e., "multi-national") diplomacy is characterized by international relationships among multiple states such as the creation of the UN after World War II for the purposes of: 1) maintaining international peace and security; 2) developing friendly relations; 3) achieving international cooperation; and 4) harmonizing the actions of states to achieve these ends (United Nations, 1945)…

Appendix B. Call for proposals from the United States Department of State Diplomacy Lab Program to be conducting during the 2015 – 2016 Academic Year (from approximately August 2015 through May 2016).

Project No. and Title: 3. Preventing a future without antibiotics: a social science research agenda

Overview:
Antibiotics are foundational to modern medicine and agricultural productivity. Improper use of antibiotics including incomplete treatment regimens contribute to rapid emergence and spread of bacteria strains resistant to existing antibiotics. Several recent international assessments have identified antibiotic resistant as a significant global threat to health and development and have noted that we are on course to quickly enter a post-antibiotic era – an end to modern medicine. In recognition of this threat, the May 2015 World Health Assembly is expected to adopt a Global Action Plan on antimicrobial resistance (AMR).

The conservation of current antibiotics is particularly important for combatting AMR. The development of new therapeutics is critical, but ultimately a temporary fix if the global community does not practice measures to conserve antibiotics. Antibiotic stewardship is challenging because it hinges on a variety of social and behavioral phenomena. Social science, while underused in AMR efforts to date, can help to address several critical questions.

Among them:
• Which cognitive frames for reducing unnecessary antibiotic use are most appealing to the general public, or to specific target populations? Are there differences in effective frames across or within countries or regions?
• What is the effect of human movement – for example, labor migration or displacement associated with natural disasters – on adherence to long-course drug regimens? What, if any, mechanisms have been successful in maintaining adherence during times of adversity?
• Which stakeholders (governments, civil society, etc.) have strong data that could indicate best practices, and which do not?

Format of Final Product:
The team would spend one (or if desired, two) semesters developing a set of critical areas for further investigation, culminating in an article suitable for a peer-reviewed journal.

Appendix C. Missouri University of Science and Technology successful bid application for, "Preventing a Future Without Antibiotics: A Social Science Research Agenda."

> *Prof Dan Oerther (2014/5 Jefferson Science Fellow in S/GFS) will oversee through a grad-level environmental microbiology course. Assoc Prof of Microbiology, Dave Westenberg will participate using pathogenic microbiology undergrads as part of public service learning. Both faculty have reviewed the U.S. National Action Plan for Combating Antibiotic-Resistant Bacteria (2015), both faculty have published with the government, and project implementation will include social science collaborators.*

Appendix D. Representative presentation prepared by students and used by students as part of regular bi-monthly briefing with the United States Department of State during the 2015 Autumn semester, the 2016 Spring semesters, and the 2016 Autumn semester.

Antibiotic Resistance Diplomacy Lab Project Summary Report

Outline

-Introduction

-Historical Analogies – multiple examples

-Statistics

-Conveying the Message

-Infographics

-Conclusions

Introduction

-There are many historical analogies that are applicable to the current issues of antibiotics in the environment.

-These analogies can provide insight on public behavior in particular situations. Using this information, the behavior of the public in the realm of antibiotics can be examined.

-The goal is to create deliverables that can be used to stop antibiotics from finding their way into the environment. These deliverables can be a variety of things such as infographics.

Historical Analogies - Microsoft

-In 2012, a Microsoft data center in Quincy, Washington faced a $210,000 fine for underuse of power throughout the year. In response, Microsoft decided to waste that energy in an unproductive manner by burning millions of watts of energy to reach the target range of energy use during the last few weeks of December that year.

-This analogy can be closely related to the use of antibiotics in the general public in regards to underuse and disposal.

Historical Analogies – CFL bulbs

-CFL light bulbs had a peak demand with usage in homes due to the energy efficiency. However, properly disposing of these bulbs is important due to the mercury content within the bulbs.

-Antibiotics need to have proper disposal practices. The manufacturers of CFL bulbs have encouraged users to properly dispose of them, and the EPA has a guide to disposing of them if broken.

Historical Analogies - electronics

-Think of how electronics were disposed of decades ago compared to now. There has been movements to encourage the public to recycle electronics rather than throw them away. To an extent, society has managed to increase the proper care and disposal of electronics.

-Both electronics and antibiotics are produced on a large scale. What do we do with what is left over? Increase awareness to keep these antibiotics out of the environment?

Historical Analogies – motor oil

-Motor oil is a common fluid that can have serious consequences when it finds it's way into the environment. When oil is changed, incentives such as cash back for the used oil are in place in some locations to keep used motor oil out of the environment.

-Public awareness in regards to disposal is crucial to keep antibiotics out of the environment. Incentives similar to motor oil industry could maybe be used.

Historical Analogies - vaccinations

-In Norway, fish farmers have begun to switch from antibiotics to vaccinations for the fish. The vaccinations have had surprisingly good results and have provided a great alternative to the use of antibiotics.

-Though maybe out of the scope of public awareness, this provides a great example of innovation to replace antibiotics in the animal farming industry and is still worth mentioning.

Historical Analogies - BPA

-In the United States, as more people began to learn about BPA and how harmful it was, many began to push to ban it in some products. As a result, BPA is banned in certain products in select states, along with help from the FDA.

-This is a great analogy in terms of public awareness. If the deliverables produced could inform the public that it is better to finish a full prescription of antibiotics during the prescribed period, that would be a major success for this project.

Historical Analogies – water use

-In Australia, there are many restrictions that are placed onto water usage. Although some aren't monitored, citizens are encouraged to abide by the restrictions.

-In Australia, education from the government about the risks of overuse of water has led to conservation of water. Education for finishing antibiotics can potentially increase the number of prescriptions that are finished.

Statistics

-2011: 842 antibiotic prescriptions per 1000 people in the US.

-For children up to the age of 9 and elderly people age 65 and older, these rates exceed 1000 prescriptions per 1000 people.

-Women are twice as likely to receive prescriptions.

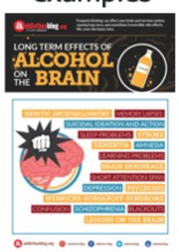
-Antibiotics are the most common cause of emergency department visits for adverse drug events in children under the age of 18.

Conveying the Message

-There are multiple approaches to making the public aware of issues. With the many different forms of media that are available to people everyday, there are many options to reach out to the public.

-To increase public awareness in regards to antibiotics, media such as infographics should be used. They could even be placed onto online media such as Facebook, which is easily accessible to many people.

Infographics – examples



Infographics – existing WHO

Conclusions

-There are several historical analogies that can be applied to antibiotics in the environment due to a lack of public awareness.

-Infographics and other media can be analyzed in order to get an idea of how to approach the issue of public awareness in relation to antibiotics.

Appendix E. Call for proposals from the United States Department of State Diplomacy Lab Program to be conducting during the 2017 – 2018 Academic Year (from approximately August 2017 through May 2018).

Project 77
Messaging Anti-Resistance! - Public Communication Tools to Combat Antibiotic-Resistant Bacteria.
Office of International Health and Biodefense (OES/IHB)

Overview:
This Diplomacy Lab project focuses on designing effective culturally sensitive multimedia messaging tools to raise public awareness of the risks associated with antibiotic pollution and antibiotic-resistant pathogens, particularly in low resource, and low infrastructure regions. We envision that the project participants will design digital (e.g. electronic communication media) and hard-copy (e.g. public posters) presentations that concisely express the need for behavior modification regarding antibiotic stewardship. Such messaging tools may be suitable for display in health care facilities and community clinics, pharmaceutical vendor shops, polluted environments, and publications. For example, such health communication tools have been judged to be effective deterrents against tobacco use and excessive alcohol consumption. In the case of antibiotics, messaging may be used to (1) prevent consumers from disposing expired antibiotics into the environment (e.g. flushing down the drain); (2) prevent consumers from purchasing counterfeit antibiotics; (3) educate patients about the proper use of antibiotics for the right diagnosis and correct dosage; (4) provide instructions about avoiding environments likely to be hotspots for excessive antibiotic levels and antibiotic resistant pathogens.

WHY THIS PROJECT IS NECESSARY AND HOW IT IS RELEVANT TO DIPLOMACY: Antibiotic resistance is a significant global threat to economic growth, social justice, and the protection of human and ecosystem health. "Combatting Antibiotic-Resistant Bacteria" - the U.S. Presidential Executive Order issued in September 2014 focused national attention on a new and growing threat to human health and the environment by noting that the "Centers for Disease Control and Prevention (CDC) estimates that annually at least two million illnesses and 23,000 deaths are caused by antibiotic-resistant bacteria in the United States alone." The order noted further that "Detecting, preventing, and controlling antibiotic resistance requires a strategic, coordinated, and sustained effort. It also depends on the engagement of governments, academia, industry, healthcare providers, the general public, and the agricultural community, as well as international partners." At the 2016 United Nations General Assembly meeting, all nations committed to address the emergence and spread of antimicrobial resistance (AMR), which is increasingly responsible for premature deaths worldwide, while also increasing the cost of treating common infections. A detailed understanding of how bacteria are exposed to antibiotics is needed to effectively address this threat [exposure to antibiotics helps "select" *for resistant bacteria]; however currently we have a thorough inability to satisfactorily answer fundamental questions about the sources, fate, and impact of antibiotics - in particular in the environment where environmental pollution by antibiotics a potential driver of resistance among pathogens is. The production, distribution, usage, disposal and environmental fate of antibiotics cut across many different sectors of society; informatics tools for "citizen science" to facilitate public data gathering on the antibiotic lifecycle is essential. This diplomacy lab project will contribute to U.S. leadership on using scientific data and creative social media strategies to inform policy, and to support knowledge sharing toward the development of action plans to combat antibiotic resistance in other countries. For example, by mobilizing public health education and participatory avenues for data collection on sources of antibiotic pollution into the environment can help scientists to identify and map hotspots of antibiotic pollution, and to develop intervention strategies at the time and place where high levels of antibiotics breed resistance among potential human pathogens.*

Format of Final Project:
Prototype messaging tools including videos, appropriately sized paper posters, and audio recordings suitable for public radio-broadcast.
Potential Areas of Useful Expertise or Interest: Communication Science; Health Education; Informatics.

Comments:
At the U.S. Department of State, the Office of International Health and Biodefense (IHB) is the primary office responsible for a variety of international health issues. IHB takes part in U.S. Government policymaking on infectious disease, environmental health, non-communicable disease issues, global health security, antimicrobial resistance, and counterfeit and substandard medications. Therefore, this Diplomacy Lab project will contribute to the major international effort by the United States government toward global strategy for reducing the antibiotic resistant infections to the global burden of disease. Project participants will be benefit from the expertise of teams of experts who are working on the technical and policy dimensions of antibiotics as environmental pollutants. In September 2016, the team at IHB hosted an international workshop on antibiotic lifecycle mapping in the Lower Mekong Region, with participants from several countries, the Society for Environmental Toxicology and Chemistry, and the United States Geological Survey.
The primary contact for this diplomacy lab project is a Jefferson Science Fellow of the National Academies of Sciences, Engineering, and Medicine, while working as a Foreign Affairs Officer in the Bureau of Oceans, Environmental and Scientific Affairs' Office of International Health and Biodefense (OES/IHB).

For additional information on the State Department of International Health and Biodefense, see: https://www.state.gov/e/oes/intlhealthbiodefense/);

For additional information on the U.S. President's Executive Order on "Combatting Antibiotic- Resistant Bacteria", see: https://www.whitehouse.gov/the-press-office/2014/09/18/executive- order-combating-antibiotic-resistant-bacteria.

For additional information on the United Nations High Level Meeting on Antimicrobial resistance, please visit: http://www.un.org/pga/71/2016/09/21/press-release-hl-meeting-on-antimicrobial-resistance/.

Appendix F. Missouri University of Science and Technology successful bid application for, “Messaging Anti-Resistance! - Public Communication Tools to Combat Antibiotic-Resistant Bacteria.”

> *In Autumn 2015, Spring 2016, and Autumn 2016, Oerther and three teams of students worked on a prior DipLab project exploring the use of social science to address antibiotic resistance. Oerther would enjoy continuing work on antibiotic resistance via DipLab. In Autumn 2017, a graduate level microbiology course will be available to participate, and in Spring 2018 an undergraduate level public health class will be available to participate. Based upon expertise and past experience, the order of preference would be project 77 (messaging tool), 75 (app), then 76 (lab on stick). Depending upon interest from IHB, number of other bids, and number of enrolled students, Oerther may be able to take on two projects simultaneously.*

Appendix G. Survey instrument for collecting community data.

Date: Time: Location:
Name of researcher:

Would you be willing to spend a few minutes reviewing some materials about Antibiotic Resistance?

I'd like to ask you a few questions, show you some information, and ask a few follow-up questions.

The entire process should take less than five minutes.

It's entirely anonymous and voluntary, and you can stop at any time.

Are you willing to participate? Yes No

Yes No **Are you an American Citizen?** (if yes, show Missouri S&T materials; else show WHO materials)

Yes Noe Have you completed a degree from an accredited institution of higher education?

I'm going to ask you a series of multi-choice questions. I'll read a statement, and then I'll read possible answers. After I've read all of the answers, please indicate your ONE choice.

Question one, antibiotics are powerful medicines that help to fight:
a) Viruses
b) Bacteria
c) All microbes

Question two, antibiotic resistance happens when my body becomes resistant to antibiotics:
a) True
b) False

Question three, antibiotic-resistant bacteria can spread to humans through:
a) Contact with a person who has an antibiotic-resistant infection
b) Contact with something that has been touched by a person who has an antibiotic-resistance infection (e.g., a health-workers' hands or instruments in a health facility with poor hygiene)
c) Contact with live animal, food or water carrying antibiotic-resistant bacteria
d) All of the above

Question four, what can happen if I get an antibiotic-resistance infection?
a) I may be sick for longer
b) I may have to visit my doctor more or be treated in a hospital
c) I may need more expensive medicine that may cause additional side effects
d) All of the above

Question five, antibiotic resistance is already out of control, and it's only getting worse. There's nothing I can do:
a) True
b) False

Question six, I can help tackle antibiotic resistance if I:
a) Share my antibiotics with my family when they are sick
b) Get antibiotics as soon as I feel sick – either directly from the pharmacy or a friend
c) Keep my vaccinations up to date

Thank you for answering my questions.

Now, I would like to show you some information. I would like for you to spend a moment reading this information. Afterwards, I will ask you some additional questions.

For American Citizens, provide information from Missouri S&T, for all others, provide information from the WHO.

Pause.

Thank you for taking time to review the information I provided. I would like to ask you some follow-up questions.

Question seven, antibiotics are powerful medicines that help to fight:

d) Viruses
e) Bacteria
f) All microbes

Question eight, antibiotic resistance happens when my body becomes resistant to antibiotics:

c) True
d) False

Question nine, antibiotic-resistant bacteria can spread to humans through:

e) Contact with a person who has an antibiotic-resistant infection
f) Contact with something that has been touched by a person who has an antibiotic-resistance infection (e.g., a health-workers' hands or instruments in a health facility with poor hygiene)
g) Contact with live animal, food or water carrying antibiotic-resistant bacteria
h) All of the above

Question ten, what can happen if I get an antibiotic-resistance infection?

e) I may be sick for longer
f) I may have to visit my doctor more or be treated in a hospital
g) I may need more expensive medicine that may cause additional side effects
h) All of the above

Question eleven, antibiotic resistance is already out of control, and it's only getting worse. There's nothing I can do:

c) True
d) False

Question twelve, I can help tackle antibiotic resistance if I:

d) Share my antibiotics with my family when they are sick
e) Get antibiotics as soon as I feel sick – either directly from the pharmacy or a friend
f) Keep my vaccinations up to date

Thank you for taking time to participate in my study.

Appendix H. Infographic (two-page) available from the World Health Organization.

Everyone has a

ROLE TO PLAY

You can help prevent antibiotic resistance

Preventing infection can reduce the use of antibiotics, and limit the spread of antibiotic resistance. Good basic hygiene is one of the most effective ways to reduce the risk of infection.

You can reduce the risk of infection by:

- ...**washing your hands** properly
- ...preparing food **hygienically**
- ...**limiting close contact** with others when you are sick
- ...practicing **safer sex**
- ...keeping your **vaccinations up-to-date**
- ...and, standing up for your right to **safe water and sanitation**

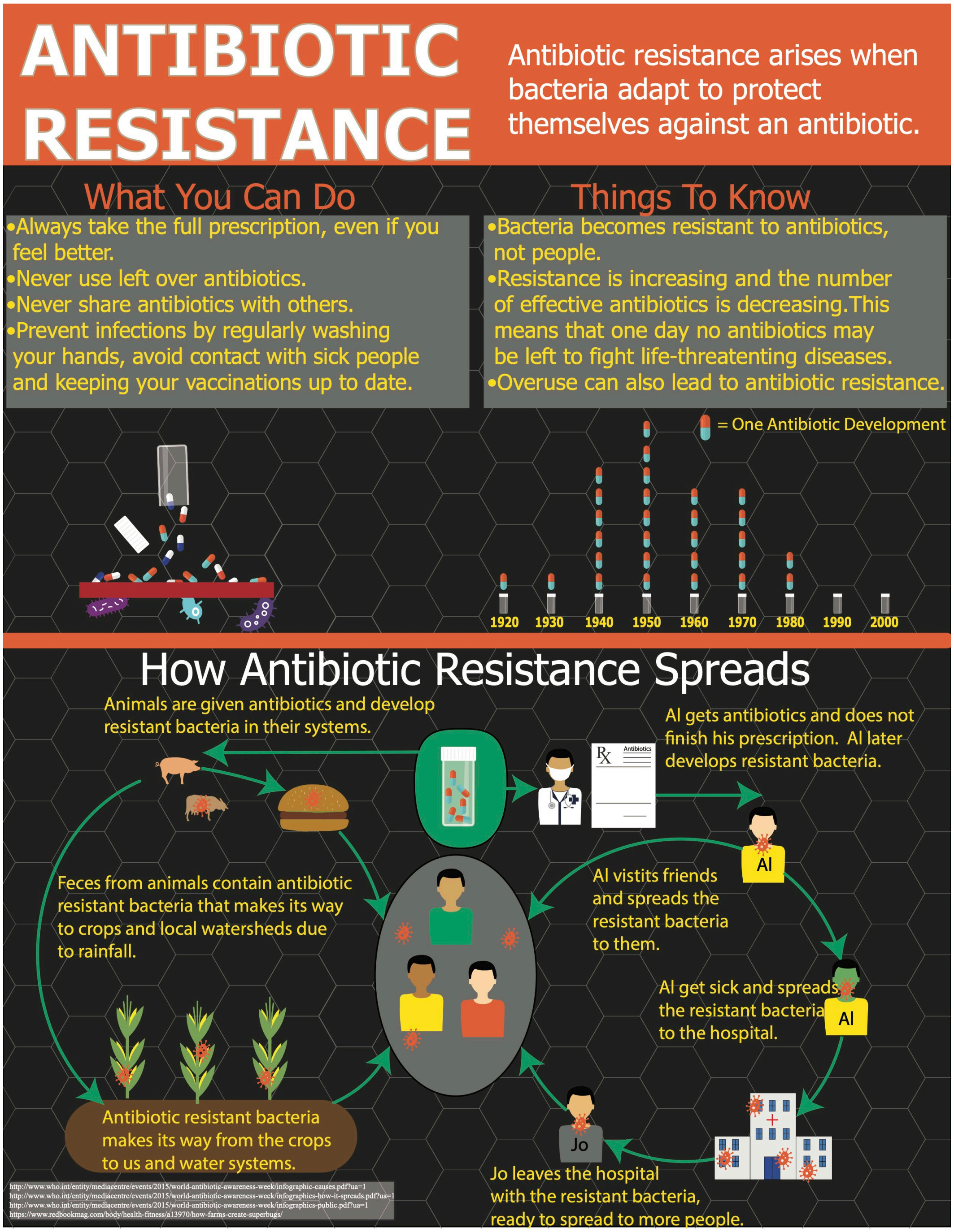
You can also reduce the spread of antibiotic resistance by:

- ...**not sharing antibiotics** with others
- ...and, **always following the advice of a qualified health care professional when taking antibiotics**

HANDLE ANTIBIOTICS WITH CARE

World Health Organization

Appendix I. Infographic (one-page) developed by students at the Missouri University of Science and Technology in the 2017 Autumn semester and 2018 Spring semester.



Appendix J. Representative written report prepared by students and submitted by students to the United States Department of State during the 2018 Autumn semester and in the 2019 Spring semester and 2019 Autumn semester.

Title: **Infographic Effects on the Understanding of Antibiotic Resistance**

Abstract

Antibiotic resistance is a paramount threat facing the world at an international level. Improper use of antibiotic drugs is the primary cause of this global threat. The purpose of this study is to analyze the effectiveness of infographics in educating the public on the risk and mitigating factors associated with antibiotic resistance. This goal was achieved by publishing an infographic outlining information on antibiotic resistance and then testing the effectiveness of the infographic using a simple survey sample of convenience interviewing 234 people in the Rolla, Missouri and neighboring communities. The analysis from this survey show that infographics are effective methods for educating the public, with the largest increases in knowledge witnessed in non-college and non-United States citizen individuals. These increases in knowledge as shown by the results of the survey conclude that infographics are a valuable option for the mass conveyance of useful information that can be easily understood by most individuals.

Introduction

Antibiotic resistance is one of the largest public health crises that the world will face in contemporary history. In the United States alone, at least 2.8 million people get an infection caused by antibiotic resistance while an additional 35,000 people die from antibiotic resistant infections (CDC, 2019). Notable causes for antibiotic resistance include incorrect use of prescribed antibiotic drugs, over prescribed antibiotic drugs, and improper and overuse of antibiotics for animal livestock in agriculture. Removing the human element of incorrect use will mitigate or eliminate the increase of antibiotic resistance. In order to achieve this result, educating the public on the risk and prevention of antibiotic resistance is a valuable option. The use of infographics is a potential option for educating the public. Infographics have seen a surge of use across multiple platforms with overwhelming success (Forbes, 2017). The purpose of this study is to analyze the effectiveness of infographics in educating the public, therefore, survey data was collected from a questionnaire on antibiotic resistance in conjunction with the use of an infographic.

Methods

The methods for this study comprised of an iterative process between multiple engineering classes located at Missouri University of Science and Technology. Classes were given a term project style assignment with the product then being used for the next iteration of the overall study. These term projects were given the title of diplomacy lab.

(a) Construct the antibiotic resistance infographic

Research was conducted on currently existing infographics with an emphasis on infographics published by the Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO). These graphics were reviewed for effectiveness and evaluated in terms of demographics and targeted audience to gauge the overall usefulness in conveying the intended message. From these results, the class was tasked with brainstorming and creating an infographic that would effectively convey useful information that would aid in educating the public on the risk and mitigating facts associated with antibiotic resistance.

(b) Construct the survey

To gauge the effectiveness of the infographic, the primary purpose of this study, a survey comprised of questions to evaluate the public's baseline knowledge of antibiotic resistance and the increase in knowledge of antibiotic resistance after being introduced to the infographic was created. Research was conducted on survey methods that could test for a "before and after" styled measurable result. The class was then tasked with generating a survey that could effectively test if the infographic created for this study was in fact effective at increasing the public's knowledge of antibiotic resistance.

(c) Conduct the survey using different delivery platforms

The survey generated by the class was then used to test the effectiveness of the infographic in two different methods. The survey was conducted in person by students in an interview type setting located across the Missouri University campus in Rolla, Missouri and limited locations outside of the Rolla area. These surveys were conducted as samples of convenience. In addition, an internet-based survey was created and published, which allowed users to take the survey from a website-based setting. This method, although not as direct, allowed for a much larger pool of date from the international population.

Results

(a) Published antibiotic resistance infographic

The infographic that was developed for the study is comprised of three major sections used to aid in educating the public. The infographic is divided in (1) bullet points for key points that if understood, would eliminate misuse of antibiotic drugs, (2) visual table representing the number of new available antibiotic drugs per decade, and (3) a diagram showing the two primary sources of antibiotic resistance found in agriculture and prescription antibiotics. The primary purpose of this infographic is to allow the easy conveyance of simple visual information.

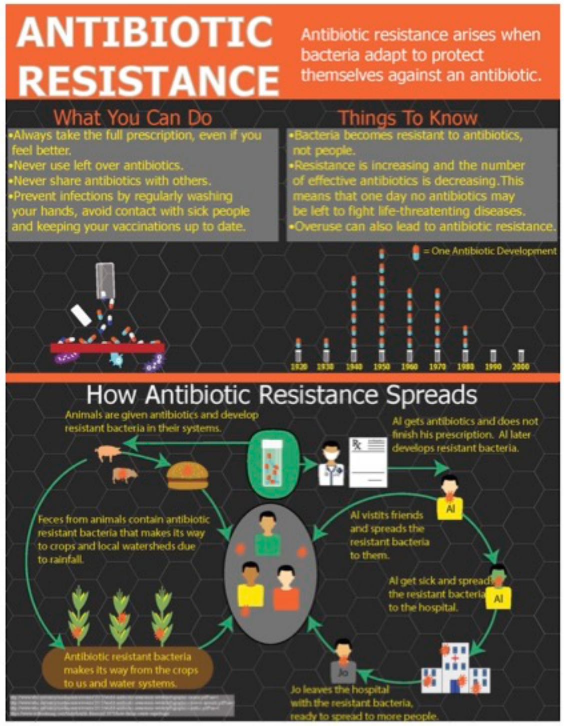


Figure 1. Antibiotic resistance infographic used during before and after survey.

(b) Published (6) question survey

The final survey questionnaire comprised of six questions. The questions were asked twice to the individual being surveyed. Once before and once after the introduction of the infographic.

Table 1.

Six question survey used for sample of convenience used for both before and after introduction on infographic

Question one, antibiotics are powerful medicines that help to fight:
a) Viruses
b) Bacteria
c) All microbes
Question two, antibiotic resistance happens when my body becomes resistant to antibiotics:
a) True
b) False
Question three, antibiotic-resistant bacteria can spread to humans through:
a) Contact with a person who has an antibiotic-resistant infection
b) Contact with something that has been touched by a person who has an antibiotic-resistance infection (e.g., a health-workers' hands or instruments in a health facility with poor hygiene)
c) Contact with live animal, food or water carrying antibiotic-resistant bacteria
d) All of the above
Question four, what can happen if I get an antibiotic-resistance infection?
a) I may be sick for longer
b) I may have to visit my doctor more or be treated in a hospital
c) I may need more expensive medicine that may cause additional side effects
d) All of the above
Question five, antibiotic resistance is already out of control, and it is only getting worse. There's nothing I can do:
a) True
b) False
Question six, I can help tackle antibiotic resistance if I:
a) Share my antibiotics with my family when they are sick
b) Get antibiotics as soon as I feel sick – either directly from the pharmacy or a friend
c) Keep my vaccinations up to date

(c) Collect sample of convenience data from survey responses.

The following list outlines the three distinctive demographics of the sample set.

1. The total population of 234 surveys.
2. Population of individuals with a college affiliation, which total 175 (59 non-college) individuals.
3. Population of individuals that are United States citizens, which total 190 (44 non-citizen) individuals.

Table 2.

Raw survey data showing the total population that answered each corresponding question choice and compared to before and after the infographic was introduced to the individual taking the survey. Correct answers are highlighted.

Before And After Using All 234 Survey Results			
Before:		After:	
Question 1/7			
a	40	d	6
b	171	e	214
c	23	f	14
SUM	234		234
Question 2/8			
a	146	c	74
b	88	d	160
SUM	234		234
Question 3/9			
a	2	e	1
b	4	f	1
c	13	g	11
d	215	h	221
SUM	234		234
Question 4/10			
a	7	e	7
b	17	f	6
c	5	g	1
d	205	h	220
SUM	234		234
Question 5/11			
a	28	c	40
b	206	d	194
SUM	234		234
Question 6/12			
a	2	d	1
b	24	e	25
c	208	f	208
SUM	234		234

Before And After Using Only College Affiliation			
Before:		After:	
Question 1/7			
a	26	d	5
b	129	e	158
c	20	f	12
SUM	175		175
Question 2/8			
a	107	c	60
b	68	d	115
SUM	175		175
Question 3/9			
a	2	e	0
b	3	f	1
c	9	g	10
d	161	h	164
SUM	175		175
Question 4/10			
a	4	e	6
b	13	f	5
c	2	g	1
d	156	h	163
SUM	175		175
Question 5/11			
a	20	c	24
b	155	d	151
SUM	175		175
Question 6/12			
a	1	d	1
b	19	e	19
c	155	f	155
SUM	175		175

Before And After Using Only Non-College Affiliation			
Before:		After:	
Question 1/7			
a	14	d	1
b	42	e	56
c	3	f	2
SUM	59		59
Question 2/8			
a	39	c	14
b	20	d	45
SUM	59		59
Question 3/9			
a	0	e	1
b	1	f	0
c	4	g	1
d	54	h	57
SUM	59		59
Question 4/10			
a	3	e	1
b	4	f	1
c	3	g	0
d	49	h	57
SUM	59		59
Question 5/11			
a	8	c	16
b	51	d	43
SUM	59		59
Question 6/12			
a	1	d	0
b	5	e	6
c	53	f	53
SUM	59		59

Before And After Using Only US Citizens			
Before:		After:	
Question 1/7			
a	31	d	6
b	140	e	170
c	19	f	14
SUM	190		190
Question 2/8			
a	111	c	58
b	79	d	132
SUM	190		190
Question 3/9			
a	2	e	0
b	3	f	1
c	4	g	8
d	181	h	181
SUM	190		190
Question 4/10			
a	3	e	5
b	8	f	2
c	3	g	1
d	176	h	182
SUM	190		190
Question 5/11			
a	22	c	24
b	168	d	166
SUM	190		190
Question 6/12			
a	2	d	1
b	21	e	24
c	167	f	165
SUM	190		190

Before And After Using Only Non-US Citizens			
Before:		After:	
Question 1/7			
a	9	d	0
b	31	e	44
c	4	f	0
SUM	44		44
Question 2/8			
a	35	c	16
b	9	d	28
SUM	44		44
Question 3/9			
a	0	e	1
b	1	f	0
c	9	g	3
d	34	h	40
SUM	44		44
Question 4/10			
a	4	e	2
b	9	f	4
c	2	g	0
d	29	h	38
SUM	44		44
Question 5/11			
a	6	c	16
b	38	d	28
SUM	44		44
Question 6/12			
a	0	d	0
b	3	e	1
c	41	f	43
SUM	44		44

Table 2 displays the raw sample data collected from the in person interviews. However, a better representation of the raw data is to proportion the demographic against the total population to gain better non-bias insight into specific changes in percentages. Table 3 shows the recalculation of the raw survey data.

Table 3.

Raw proportioned survey data showing the total population that answered each corresponding question choice and compared to before and after the infographic was introduced to the individual taking the survey. Correct answers are highlighted.

Before And After Using All 234 Survey Results			
Before:		After:	
Question 1/7 (Prop)			
a	17%	d	3%
b	73%	e	91%
c	10%	f	6%
SUM	1		1
Question 2/8			
a	62%	c	32%
b	38%	d	68%
SUM	1		1
Question 3/9			
a	1%	e	0%
b	2%	f	0%
c	6%	g	5%
d	92%	h	94%
SUM	1		1
Question 4/10			
a	3%	e	3%
b	7%	f	3%
c	2%	g	0%
d	88%	h	94%
SUM	1		1
Question 5/11			
a	12%	c	17%
b	88%	d	83%
SUM	1		1
Question 6/12			
a	1%	d	0%
b	10%	e	11%
c	89%	f	89%
SUM	1		1

Before And After Using Only College Affiliation			
Before:		After:	
Question 1/7 (Prop)			
a	15%	d	3%
b	74%	e	90%
c	11%	f	7%
SUM	1		1
Question 2/8			
a	61%	c	34%
b	39%	d	66%
SUM	1		1
Question 3/9			
a	1%	e	0%
b	2%	f	1%
c	5%	g	6%
d	92%	h	94%
SUM	1		1
Question 4/10			
a	2%	e	3%
b	7%	f	3%
c	1%	g	1%
d	89%	h	93%
SUM	1		1
Question 5/11			
a	11%	c	14%
b	89%	d	86%
SUM	1		1
Question 6/12			
a	1%	d	1%
b	11%	e	11%
c	89%	f	89%
SUM	1		1

Before And After Using Only Non-College Affiliation			
Before:		After:	
Question 1/7 (Prop)			
a	24%	d	2%
b	71%	e	95%
c	5%	f	3%
SUM	1		1
Question 2/8			
a	66%	c	24%
b	34%	d	76%
SUM	1		1
Question 3/9			
a	0%	e	2%
b	2%	f	0%
c	7%	g	2%
d	92%	h	97%
SUM	1		1
Question 4/10			
a	5%	e	2%
b	7%	f	2%
c	5%	g	0%
d	83%	h	97%
SUM	1		1
Question 5/11			
a	14%	c	27%
b	86%	d	73%
SUM	1		1
Question 6/12			
a	2%	d	0%
b	8%	e	10%
c	90%	f	90%
SUM	1		1

Before And After Using Only US Citizens			
Before:		After:	
Question 1/7			
a	16%	d	3%
b	74%	e	89%
c	10%	f	7%
SUM	1		1
Question 2/8			
a	58%	c	31%
b	42%	d	69%
SUM	1		1
Question 3/9			
a	1%	e	0%
b	2%	f	1%
c	2%	g	4%
d	95%	h	95%
SUM	1		1
Question 4/10			
a	2%	e	3%
b	4%	f	1%
c	2%	g	1%
d	93%	h	96%
SUM	1		1
Question 5/11			
a	12%	c	13%
b	88%	d	87%
SUM	1		1
Question 6/12			
a	1%	d	1%
b	11%	e	13%
c	88%	f	87%
SUM	1		1

Before And After Using Only Non-US Citizens			
Before:		After:	
Question 1/7			
a	20%	d	0%
b	70%	e	100%
c	9%	f	0%
SUM	1		1
Question 2/8			
a	80%	c	36%
b	20%	d	64%
SUM	1		1
Question 3/9			
a	0%	e	2%
b	2%	f	0%
c	20%	g	7%
d	77%	h	91%
SUM	1		1
Question 4/10			
a	9%	e	5%
b	20%	f	9%
c	5%	g	0%
d	66%	h	86%
SUM	1		1
Question 5/11			
a	14%	c	36%
b	86%	d	64%
SUM	1		1
Question 6/12			
a	0%	d	0%
b	7%	e	2%
c	93%	f	98%
SUM	1		1

Discussion

(a) Antibiotic resistance infographic effectiveness

The magnitude of the effectiveness of the infographic can be determined in the percent increase between the before and after results of the survey shown in Table 3. All three demographic groups, that is, the total population, college affiliation, and US citizenship, all saw a distinctive increase in the number of correctly answered survey questions after the individual being surveyed was introduced to the infographic.

(b) Published (6) question survey effectiveness

The published survey used for this study consisted of six questions asked before and after the individual being surveyed was introduced to the infographic from figure 1. Generally, there was an overall increase in the percentage of correctly answered question after the individual was introduced to the infographic across all six questions with the exception of questions 5(11) and 6(12). These two question saw a slight decrease between the before and after correct answer rate across all three demographic categories. This leads to a number of potential conclusions, namely: 1) that questions 5 and 6 may have been poorly executed; 2) the infographic failed to properly educate; or 3) these questions capture the variation that is present in the sample and may serve as a type of "convenience internal control", which increases confidence in the differences observed in the other questions. Each scenario is plausible. Bias may have existed in the survey since the number of questions only totaled six, and the two questions being considered were simply true/false, which does a poor job of representing knowledge. The survey platform of in-person interview convenience sampling was successful in capturing a wide range of individuals from different demographics that allowed for a more conclusive analysis of the sample data.

(c) Data analysis of the collection survey samples

Considering table 3, three key points can be concluded from the percent changes between the before and after survey data.

1. College affiliation saw the smallest change between the two surveys.
2. Non-college and non-US citizens saw significant increases in the correct answer rate between surveys.
3. Non-US citizens benefitted the greatest from the infographic.

Question 5 remains a source of concern due to a decline in correct answers from all demographics, which further suggests a possibility of survey instrument bias as described in the previous section.

A possible explanation for these three trends is that infographics are most effective on people that may not have been exposed to the underlying concepts until the initial survey. Infographics by nature are simple visual representations of key facts that can be understood by those that do not potentially have a higher education or speak English as a primary language. This conclusion further reinforces the effectiveness of infographics for use in a public setting.

Conclusion

The concept of using infographics as a method for educating the public is a valuable option to aid in the reduction and elimination of antibiotic resistance. While perhaps difficulty to engineers specifically, in general it may be assumed that infographics are easy to create for experienced experts in communication and can be placed in high visibility public locations. In turn, this allows for a potential increase in public awareness of the concepts displayed on the infographic as proven with this study. Although not a sole source solution against the threat of antibiotic resistance, infographics are a valuable option in the increased mitigation.

References

Centers for Disease Control and Prevention. Antibiotic Resistance Treats in the United States 2019, Antibiotic Resistance Treats in the United States 2019 (2019). Retrieved from https://www.cdc.gov/drugresistance/pdf/threats-report/2019-ar-threats-report-508.pdf

Conner, C. (2017, October 19). The Data Is In: Infographics Are Growing And Thriving In 2017 (And Beyond). Retrieved December 5, 2019, from https://www.forbes.com/sites/cherylsnappconner/2017/10/19/the-data-is-in-infographics-are-growing-and-thriving-in-2017-and-beyond/#1f613330137c.

Appendix J. Updated infographic (one-page) developed by students at the Missouri University of Science and Technology in CArE 6601 Biological Principles in the 2022 Autumn semester.

Appendix K. Representative, responses of students relevant to the Diplomacy Lab project on antibiotic resistance. Collected during end-of semester, open-ended questions included as part of an anonymous course assessment conducted by the Missouri University of Science and Technology.

Course(s)	**Representative student comment(s) in response to open ended questions asking about strengths, weakness, or suggestions for improvements. Only comments directly related to Diplomacy Lab and antibiotic resistance module were included.**
2015, Autumn; 6601	None.
2016, Spring; 5650	Also it's great that you do work for the state department and partnered with them for the diplomacy, but educationally I think it is unacceptable to force student participation in the diplomacy lab as the only possible way to get an A in the class.
2016, Autumn; 6601	None.
2017, Autumn; 6601	None.
2018, Spring; 5001	I would like to have started the model UN and work on antibiotic resistance earlier and increased the span of which we completed the tasks.
2018, Spring; 5650	I enjoyed the diplomacy lab and public health fair projects - they were a welcome change of pace as well as very worthwhile. I love the real world discussion! I am starting to have a major interest in public health... thanks for that!
2018, Autumn; 6601	Strengths - very good application to environmental engineering in compared to other such courses I have taken, because often microbiology courses in an environmental engineering curriculum can turn into pure microbiology losing sight of environmental engineering but that was not the case in this course as we discussed how to raise awareness of antibiotic resistance.
2019, Spring; 5001	Dr. Oerther is clearly knowledgeable in his field, but it's also clear that teaching his classes is not a high priority. He was away (out of the state and sometimes country) for three weeks during the semester for State Department work.
2019, Spring; 5650	He sticks to the material for assignments but also makes it relatable or memorable with real world examples like diplomacy lab for antibiotic resistance.
2019, Autumn; 6601	None.
2020, Spring; 5001	This was excellent exposure to a topic that I was not overly familiar with, both the UN and antibiotic topics, I had to actually invest time in my assignments that made the difference for my grade, that was something I really did enjoy and what I came here for, being forced to learn, use my brain and use skills that I had developed over time.
2020, Spring; 5650	I do not think I have had an instructor stimulate and motivate me more than Dr. Oerther has to become a better engineer. I chose this class simply because it sounded kind of cool and because it fit my schedule. Little did I know that Dr. Oerther would bring forth the ideas of how much responsibility falls on the engineer in making sure that the public is safe and continues to grow not only in their physical but mental and spiritual health. While the content of 5650 may not be too applicable to my preferred field in the future, I will almost certainly remember the duty to the public I have with my profession as an engineer. Thank you Dr. Oerther.
2020, Autumn; 6601	None
2021, Spring; 5650	This course showed a different side in environmental engineering in how different fields can collaborate (and should!) to solve complex problems like

	antibiotic resistance. It also showed that sometimes perfect scenario goals cannot be feasibly reached, so determining the best use of resources in relation to quality of results must be considered.
2021, Autumn; 6601	The course definitely highlights the biological part of the engineering industry, especially antibiotic resistance and public health. Especially as environmental engineers. I never knew engineering and biology were this related.
2022, Spring; 5650	None.
2022, Autumn; 6601	None.