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# Introduction to Public Health for Environmental Engineers: Results from a Three-Year Pilot

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# Introduction to Public Health for Environmental Engineers: Results from a Three-year Pilot

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Professor Daniel B. Oerther, PhD, PE, BCEE, CEng, D.AAS, F.AAN, F.RSA, F.RSPH joined the faculty of the Missouri University of Science and Technology in 2010 after ten years on the faculty of the University of Cincinnati where he served as Head of the Department of Civil and Environmental Engineering. Since 2014, he has concurrently served as a Senior Policy Advisor to the U.S. Secretary of State in the areas of environment, science, technology, and health (ESTH). Oerther earned his B.A. in biological sciences and his B.S. in environmental health engineering from Northwestern University (1995), and he earned his M.S. (1998) in environmental health engineering and his Ph.D. (2002) from the University of Illinois, Urbana-Champaign. He has completed postgraduate coursework in Microbial Ecology from the Marine Biology Laboratory, Environmental Health from the University of Cincinnati, Public Health from The Johns Hopkins University, and Public Administration from Indiana University, Bloomington. Oerther is a licensed Professional Engineer (PE, DC, MO, and OH), Board Certified in Environmental Engineering (BCEE) by the American Academy of Environmental Engineers and Scientist (AAEES), and registered as a Chartered Engineer (CEng) by the U.K. Engineering Council. He is recognized as a Diplomate of the American Academy of Sanitarians (D.AAS). His scholarship, teaching, service, and professional practice focus in the fields of environmental biotechnology and sustainable development where he specializes in promoting Water, Sanitation, and Hygiene (WaSH), food and nutrition security, energy efficiency, and poverty alleviation. Oerther's awards for teaching include the best paper award from the Environmental Engineering Division of ASEE, as well as recognition from the NSPE, the AAEES, and the Association of Environmental Engineering and Science Professors (AEESP). He participated in both the 2006 and the 2015 conferences of the National Academies Keck Futures Initiative (NAKFI) as well as the 2011 Frontiers of Engineering Education Symposium (FOEE) of the U.S. National Academies. Oerther is a four-time recipient of Fulbright, and he has been recognized with a Meritorious Honor Award by the U.S. Department of State. Due to his collaborations with nurses and healthcare professionals, Professor Oerther has been inducted as a Lifetime Honorary Member of Sigma Theta Tau, the International Honor Society of Nursing (STTI), and he has been inducted as a Lifetime Honorary Fellow of the American Academy of Nursing (F.AAN). Dan is also a Fellow of the Royal Society of Arts (F.RSA) and a Fellow of the Royal Society for Public Health (F.RSPH).

# Introduction to Public Health for Environmental Engineers: Results from a Three-Year Pilot


## Abstract

The field of environmental engineering traces its origins to the integration of "civil engineering" infrastructure and the objectives of "public health", namely cost effective disease prevention at the community-scale. To address the urgent need to re-invigorate the "ancient" sub-specialization of "sanitary engineering" within the field of environmental engineering, a new course was created at the Missouri University of Science and Technology entitled, "Public Health for Environmental Engineers." The new course leverages available online materials disseminated by The Johns Hopkins University as well as materials disseminated by the National Environmental Health Association (NEHA) to emphasize environmental health practice in diverse communities – from urban settings in developed nations to rural villages in less developed countries. The new course employs a previously reported format including blended delivery, a flipped classroom, and mastery learning (D.B. Oerther, "Reducing costs while maintaining learning outcomes using blended, flipped, and mastery pedagogy to teach introduction to environmental engineering," in *Proceedings of the 2017 ASEE Annual Conference & Exposition, Columbus, OH, USA, June 25-28, 2017*. [Online]. Available: https://peer.asee.org/28786. [Accessed April 26, 2018]). This current article summarizes the course content, pedagogical approach, and the results of assessments of three offerings of "Public Health for Environmental Engineers" to a total of 79 students in the Spring Semesters of 2016, 2017, and 2018. According to the results of the assessments, some students resisted the blended learning delivery format (i.e., "The professor gets paid a lot, and he shouldn't use available online materials for teaching. He should make us purchase a text book and cover it in lecture"), and other students resisted the pedagogical choice of active learning (i.e., "Complete abuse of power; the professor creates an environment that is not conducive to learning by forcing students to answer questions during discussion"). Other students responded positively to the course content (i.e., "I learned a lot of practical environmental health information that I plan to use in practice"). Future work should: 1) follow-up with students to identify the value of the course in their professional practice after graduation; 2) assess changes in student attitudes and beliefs from before and after the course; and 3) replicate the course at other institutions to evaluate the effectiveness of the course content and delivery approach independent of the personality of the instructor and with a variety of student types.


## Introduction

The field today known as "environmental engineering" emerged formally with the creation of two organizations, namely, the American Academy of Environmental Engineers and Scientist (AAEES) [2] – which recognizes leadership and excellence through certification of environmental engineers and scientists and provides professional development opportunities for students and practitioners – and the Association of Environmental Engineering and Science Professors (AEESP) [3] – which promotes excellence in environmental engineering and science education and research by providing leadership, promoting cooperation, and serving as a liaison between members and other professional societies, governmental agencies, industry, and nonprofit organizations. The AAEES was born on October 21, 1955 when the American Sanitary Engineering Intersociety Board (ASEIB) was incorporated under the laws of the State of Delaware with the purpose of creating a roster of Diplomates recognized for their competence in the practice of sanitary engineering [2]. The AEESP was born on December 5, 1965 when a group of 21 professors from 14 universities acted on a motion to form the American Association of Professors in Sanitary Engineering (AAPSE) [3]. Over time, both organizations formally dropped “sanitary” from their titles [4], and the field of environmental engineering and science expanded substantially from its origins in public health [5] [6] including the development of a variety of courses focused upon diverse sub-specializations such as “molecular biology tools” [7], “sustainable development” [8], and “science policy” [9]. Nonetheless, there remain pockets of practice and education in “sanitary engineering.” For example, the National Environmental Health Association (NEHA), founded in 1937, exists, “To advance the environmental health profession for the purpose of providing a healthful environment for all,” [10], and the American Academy of Sanitarians (AAS), founded in 1966, exists to, “elevate the standards, improve the practice, advance professional proficiency, and promote the highest levels of ethical conduct among professional sanitarians in every field of environmental health” [11].

In 1998, the final report of the National Science Foundation (NSF)-sponsored meeting, “Research Frontiers in Environmental Engineering,” raised an important question, namely, “Should the non-industrialized world follow the technology development model for wastewater treatment of the industrialized world?” [12]. Two decades later, a similar question was raised by Mihelcic and co-authors, “The environmental engineering discipline has focused much of its historical efforts in developing regions of the world on advancing environmental sustainability through improving provision of water, sanitation, and hygiene (WaSH) services. However, the skills and expertise that reside within the discipline of environmental engineering are fundamental to achieve a much broader range of sustainable development goals, including those related to health, climate, water, energy, and food security; economic development; and reduction of social inequalities” [13]. The breadth of skills and expertise of environmental engineers exhorted by Mihelcic and co-authors align well with the definition of “environmental health” promoted by NEHA, namely, “Environmental health is the science and practice of preventing human injury and illness and promoting wellbeing by identifying and evaluating environmental sources and hazardous agents; and limiting exposure to hazardous physical, chemical, and biological agents in air, water, soil, food, and other environmental media or settings that may adversely affect human health” [10].

In 2016, The Johns Hopkins University Bloomberg School of Public Health and Whiting School of Engineering announced the formation of a new academic department devoted to “tackling environmental issues and their impact on public health,” [14]. The development of a new course at the Missouri University of Science and Technology described in this paper, “Public Health for Environmental Engineers,” builds upon and utilizes available materials from 180.601.01 Environmental Health organized by Professor Jonathan Links at The Johns Hopkins University [15] as well as the REHS/RS Study Guide (Fourth Edition) published by the NEHA [16]. In three offerings of, “Public Health for Environmental Engineers,” to a total of 79 students in the Spring Semesters of 2016, 2017, and 2018, a blended format, a flipped classroom, mastery learning, and a buffet of optional summative assessments used to assign a final grade has been utilized to teaching environmental health engineering following a previously published approach

[1]. As part of the course, student demographics were collected using online Myers-Briggs testing [17] as well as a Learning Styles Inventory [18]. Student satisfaction was assessed using anonymous, online course evaluations administered using Survey Monkey after the fourth week of the course and using a campus-wide system after the fifteenth week of the course. The purpose of this paper is to share course content, pedagogical approach, the results of assessments, and the experiences gained from a three-year pilot of, "Public Health for Environmental Engineers," offered at the Missouri University of Science and Technology

**Methods**

Course Catalog Description. As published by the Missouri University of Science and Technology, the offering is described as, "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 serves 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."

Course Delivery. The offering includes: a blended format; a flipped classroom; mastery learning; and a buffet of optional summative assessments used to assign a final grade [1]. Briefly, content delivery via both online digital media and via face-to-face lecture is known as a "blended format", and some of the benefits include accommodating diverse learning styles (i.e., listening or reading) while improving student satisfaction with content delivery [19] [20]. A "flipped classroom" enhances the opportunity to use inductive learning strategies (i.e., think-pair-share) in the lecture because students preview course content before meeting face-to-face with the instructor [21] [22]. As students struggle to "grok" complex concepts, "mastery learning" – where students demonstrate knowledge of a concept before moving on to the next concept – provides an opportunity for self-pacing to accommodate individual variation among students and among concepts [23]. And finally, offering a buffet of optional summative assessments – after minimum mastery has been achieved – provides a means of informal grade contracting where students opt to demonstrate their knowledge – and earn a grade – in a manner most consistent with their personal preferences (and likely their perception of the path of least resistance) [1].

Course Content. The course consists of seventeen modules, including:

1) a required introduction to: blended, flipped, mastery learning, and buffet assessment;
2) two optional term projects;
3) seven required fundamental units; and
4) seven required practice units.

The two optional term projects are selected to reinforce the interrelationship among the material covered in the fundamental units and the material covered in the practice units. One optional term project completes a Diplomacy Lab offering provided by the United States Department of State [9]. And the other optional term project designs and executes a local community health fair event as part of interprofessional education (IPE) in environmental health practice [24]. The content of the seven required fundamental units, include: a) introduction to environmental health; b) human-environment interaction; c) exposure, dose, response; d) toxicology; e) carcinogenesis; f) occupational health; and g) risk assessment and management. Online, required lectures are selected from publically available, massively online open course materials posted by The Johns Hopkins Bloomberg School of Public Health via Coursera [15]. The content of the seven required practice units, include: h) statutes and regulations + disaster sanitation; i) biological hazards; j) food, water, wastewater exposures; k) solid, hazardous, radiological exposures; l) air, housing, and pools exposures; m) occupational exposures; and o) institutions + facilities. Required readings are selected from the Registered Environmental Health Specialist / Registered Sanitarian Study Guide published by the NEHA [16].

Course Assessment. Student demographics were collected using online Myers-Briggs testing [17] as well as a Learning Styles Inventory [18]. Student satisfaction was collected using anonymous online course evaluations administered using Survey Monkey after the fourth week of the course, and using a campus-wide system after the fifteenth week of the course. Mastery learning was assessed using a mixture of instruments including multiple-choice vocabulary quizzes, true/false statements from the online required lectures and true/false statements from the required readings. Students who demonstrated full mastery before the deadlines stated in the syllabus received a grade of "C" for the course. To earn a higher grade, a buffet of optional summative assessments was utilized. The optional term projects were assessed using rubric grading. Optional summative assessments for the seven required fundamental units and the seven optional practice units included online multiple-choice questions. An optional comprehensive cumulative written final examination was provided as an additional means of summative assessment. As discussed previously [1], the use of a modified mastery learning approach allows the instructor to identify knowledge that "must-be-learned", and to separate this required knowledge from the optional knowledge that "can-be-learned".

## Results

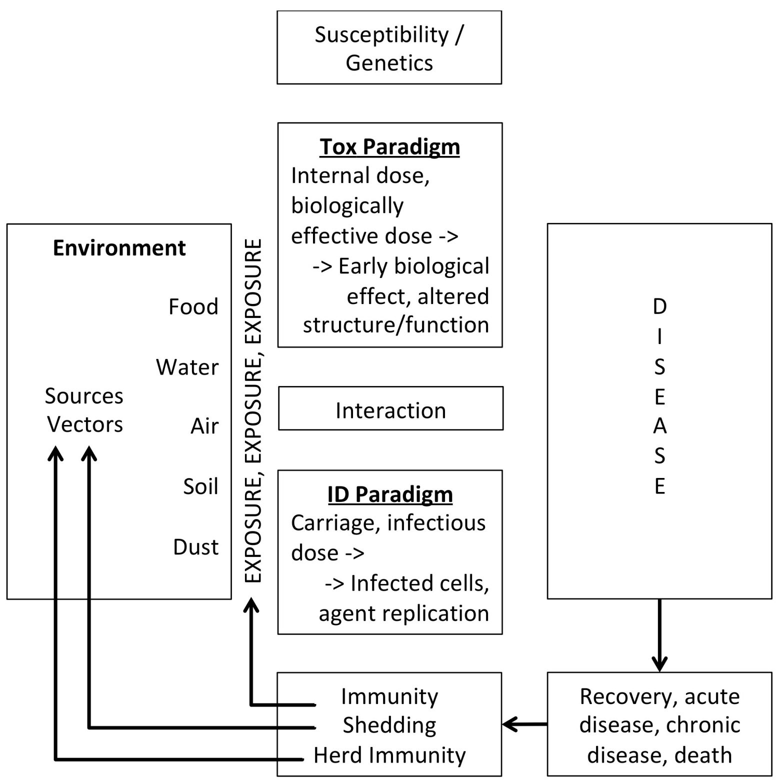
Details of Course Content. While a complete recapitulation of the entire content of, "Public Health for Environmental Engineers," is beyond the scope of this paper (please contact the author for full course content), four critical elements of the course content are discussed below, in detail.

First, because many students are unfamiliar with a blended format, a flipped classroom, mastery learning, and a buffet of optional summative assessments used to assign a final grade, it is essential to include a course module to introduce these concepts [1]. The author prefers to introduce these concepts to students using "Happy Saint Syllabus Day" as the title for the inaugural course meeting. The author distributes a hard copy of the detailed syllabus to all of the students and then proceeds to deliver a "traditional" didactic lecture introducing the details of the syllabus through a series of hand-written notes on a white board. This in the one-and-only "traditional" lecture delivered during the entire semester. Between the first and second meetings of the course, students are instructed to complete a series of online activities delivered using a

Learning Management System (i.e., Canvas, Blackboard or others). Appendix 1 includes the full instructions provided for students to complete before the second face-to-face meeting of the course.

Second, because most engineering students lack fundamental understanding of risk assessment and risk management, the toxicological paradigm is used as the organizing concept for the seven fundamental units. Originally developed in 1987 by the National Research Committee on Biological Markers, the toxicological paradigm relates exposure to clinical disease through a series of six steps and includes interaction from both nature (i.e., genetics) and nurture (i.e., diet) [25]. "Public Health for Environmental Engineers" utilizes the updated toxicological paradigm developed by researchers at The Johns Hopkins University and first published in 2010 [26]. The updated paradigm integrates toxicology and infectious disease – two of the areas where risk assessment and risk management overlap in the ancient practice of "sanitary engineering". Figure 1 includes the diagram of the modified toxicological paradigm used in, "Public Health for Environmental Engineers."

**Figure 1.** The modified toxicological paradigm integrating toxicology (Tox) and infectious disease (ID) as developed at The Johns Hopkins and originally published in 2010 [26].




Third, because most engineering students lack prior hands-on experience with the daily practices of "sanitarians," the FAT TOM and the TCS paradigms are used as examples of empirical rules-of-thumb that must be memorized and judiciously utilized in the field. FAT TOM is a mnemonic device used extensively in food service to recall the six favorable conditions necessary for proliferation of foodborne pathogens. The terms include: Food; Acidity; Time; Temperature; Oxygen; and Moisture [27]. TCS is an acronym that stands for Time/Temperature Control for Safety, and includes foods that must be processed to reduce pathogens to safe levels [28]. The REHS/RS Study Guide (Fourth Edition) published by NEHA covers FAT TOM and TCS as part of the chapter on food [16]. Additional chapters cover a further range of important, practical topics including: potable water; wastewater; solid and hazardous waste; hazardous materials; air quality and environmental noise; occupational safety and health; and others [16]. As an example of the type of content introduced during the seven required practice units, Figure 2 includes details of FAT TOM and TCS used in, "Public Health for Environmental Engineers."

And finally, because many students are unfamiliar with applying course material learned in the classroom to the workplace environment, it is essential to include a hands-on, experiential learning opportunity to solidify the "ancient" practice of "sanitary engineering" [24]. While any number of hands-on experiential learning opportunities may be selected depending upon the

**Figure 2.** An introduction to food safety including FAT TOM [25] and TCS [26].

| FAT TOM | TCS<br>Time/Temperature Control for Safety |
|---|---|
| Food | Beef, pork, veal, lamb; 145F +3min |
| | Ground meats; 156F |
| Acidity - <4.6; >7.5 | |
| | Ham; 145F +3min |
| Time − 4hrs max in danger zone | Cooked ham; 140F USDA; 165F |
| | All poultry; 165F |
| Temperature − <40F; >140F | |
| | Eggs; 160F |
| Oxygen − reduce/eliminate | Fish and shellfish; 145F |
| | Leftovers; 165F |
| Moisture − reduce/eliminate | |
| | Casseroles; 165F |
| | DANGER ZONE; 41F-135F |

preferences of the instructor, the nature of the students, and the affordability and appropriateness of local options, the author has opted to use a term-length project to design and execute a local community health fair event aimed at refresher training for existing child care employees and facilities as well as awareness raising of appropriate practices and essential regulations for potential child care employees and facilities [29]. The students in, "Public Health for

Environmental Engineers," plan a Saturday-morning event that includes a presentation on licensure as well as hands-on training in Servsafe practice and CPR. Students recruit local experts from the Phelps County Health Department and the Phelps County Regional Medical Center as well as officials from the State of Missouri and experienced mentors – directors of larger, fully licensed childcare facilities in the region. This topic was selected in consultation with the elected Commissioners of Phelps County as well as the local Extension Office of the University of Missouri – Lincoln University land-grant institutions.

Details of Pilot Results. A new course, "Public Health for Environmental Engineers," was offered in the Spring Semesters of 2016, 2017, and 2018 to a total of 79 students. Table 1 presents a summary of course demographics. As part of the REQUIRED, online lecture for Unit 0, students were directed to complete an online Learning Styles Inventory and a Myers-Briggs Personality Test. The results of these assessments were captured in questions included in the Unit 0 REQUIRED lecture quiz (see Appendix 1, below). Additional student demographics including gender and enrollment status (i.e., distance student or face to face student; Graduate student, Senior, or Junior standing; and degree program) were collected from information provided by each student and cross referenced with the database maintained by the Registrar.

As shown in Table 1, of the 79 total students who participated in the three course offerings, each class was similar in size (between 22 and 29 students). Each class was approximately 1/3 female. Visual and Auditory were the preferred single strongest Learning Styles, but a substantial number of students documented equal preference for all three styles or a similar strong preference for two of the three styles. Among the results of the Myers-Briggs Personality Test, the Jung Typology for "source of energy" indicates a slight preference for Introversion over Extroversion (i.e., 14 individuals versus 8 individuals in Spring 2016). This result is not surprising for a class predominantly of engineering students who are often stereotyped as "shy". The results for how students "gather information" indicate a slight preference for Intuition over Sensing (i.e., 16 individuals versus 12 in Spring 2017), which may indicate a slight preference for "gut feelings" and "tradition". The results for how students "make decisions" indicate a slight preference for Thinking over Feeling (i.e., 13 individuals versus 9 in Spring 2016), which may indicate a slight preference for "logic" and "rules". And finally, the most significant difference for Jung Personality Type was observed in a strong preference for Judging over Perceiving (i.e., 16 individuals versus 6 in Spring 2016), which likely indicates a strong preference for "order" and "instructions". These trends have been reported previously for students [1], and based upon these trends in Jung Personality Type, the use of clear instructions (i.e., For Your Information, FYI.doc file) has been included as part of each course unit (i.e., Appendix 1, below).

As shown in Table 1, in the Spring 2016 offering only 2 students were enrolled via distance, while approximately 1/3 of the class was enrolled via distance in Spring 2017 and 2018. This change in enrollment for, "Public Health for Environmental Engineers," corresponds to an overall trend in enrollment observed at the institution, which reflects an increase in the number of total students enrolled via distance.

As shown in Table 1, the majority of students from each offering held Senior status (i.e,. 19, 20, and 26 individuals in Spring 2016, 2017, and 2018, respectively), and were enrolled in, "Public

Health for Environmental Engineers," in their final semester of baccalaureate studies. Therefore, the student responses to course evaluations conducted during the fourth and fifteenth week of the semester may be influenced by both a sense of "maturity" (i.e., Seniors who have participated in numerous courses with a variety of different instructor types) as well as a sense of "apathy" (i.e., Senior slide before Spring Graduation and subsequent career placement).

**Table 1.** Demographics of a total of 79 students enrolled in three course offerings of "Public Health for Environmental Engineers" in the Spring semester of 2016, 2017, and 2018.

| | **Spring 2016** | **Spring 2017** | **Spring 2018** |
|---:|---:|---:|---:|
| | N = 22 | N = 28 | N = 29 |
| **Gender** | | | |
| Male | 15 | 16 | 18 |
| Female | 7 | 12 | 11 |
| | | | |
| **Learning Styles Inventory** | | | |
| Visual | 7 | 10 | 4 |
| Auditory | 6 | 4 | 11 |
| Kinesthetic | 2 | 4 | 2 |
| V, A, K all equal | 5 | 5 | 6 |
| Two higher than third | 2 | 5 | 6 |
| | | | |
| **Jung Typology** | | | |
| Extrovert (E) | 8 | 10 | 13 |
| Introvert (I) | 14 | 18 | 16 |
| Sensing (S) | 11 | 12 | 12 |
| Intuition (N) | 11 | 16 | 17 |
| Thinking (T) | 13 | 15 | 13 |
| Feeling (F) | 9 | 13 | 16 |
| Judging (J) | 16 | 24 | 22 |
| Perceiving (P) | 6 | 4 | 7 |
| | | | |
| **Enrollment status** | | | |
| Distance | 2 | 8 | 10 |
| Face to face | 20 | 20 | 19 |
| | | | |
| Graduate student | 2 | 6 | 3 |
| Senior standing | 19 | 20 | 26 |
| Junior standing | 1 | 2 | 0 |
| | | | |
| Architectural Engineering | 0 | 0 | 0 |
| Civil Engineering | 12 | 14 | 18 |
| Environmental Engineering | 10 | 13 | 9 |
| Architectural and Civil Engineering | 0 | 1 | 2 |

And finally, as shown in Table 1, the majority of the students were enrolled in the baccalaureate degree program of Civil Engineering (i.e., 12, 14, and 18 individuals in Spring 2016, 2017, and 2018, respectively) while a large minority of the students was enrolled in Environmental Engineering (i.e., 10, 13, and 9 individuals in Spring 2016, 2017, and 2018, respectively) and very small portion were dual enrolled in both Architectural and Civil Engineering degree programs (i.e., 1 individual in Spring 2017 and 2 in Spring 2018). Therefore, the student responses to course evaluations conducted during the fourth and fifteenth week of the semester should be interpreted as a mixture of "tangentially interested" and "fully engaged" with the course description (i.e., some students may have been enrolled simply because the timing of an elective course was convenient).

A summary of final grades for, "Public Health for Environmental Engineers," is presented in Table 2. In the first offering of the course, a majority of the students elected to complete only a small percentage of the buffet of optional summative assessments including the term projects, the seven fundamental units, the seven practice units, and a comprehensive, cumulative, written final examination. Interestingly, in the second offering of the course, an overwhelming majority of the students elected to complete sufficient optional assignments to earn a grade of "A" for the course. There is no immediate explanation for this change in behavior of the students among the Spring 2016 and Spring 2017 offerings. No data regarding final course grades for Spring 2018 was available at the time of publication. Future studies should attempt to ascertain if there is a "reason" for students electing to ignore or not-complete optional assignments to earn a higher grade.

**Table 2.** Summary of final course grades for "Public Health for Environmental Engineers" for the Spring 2016, 2017, and 2018 semesters.

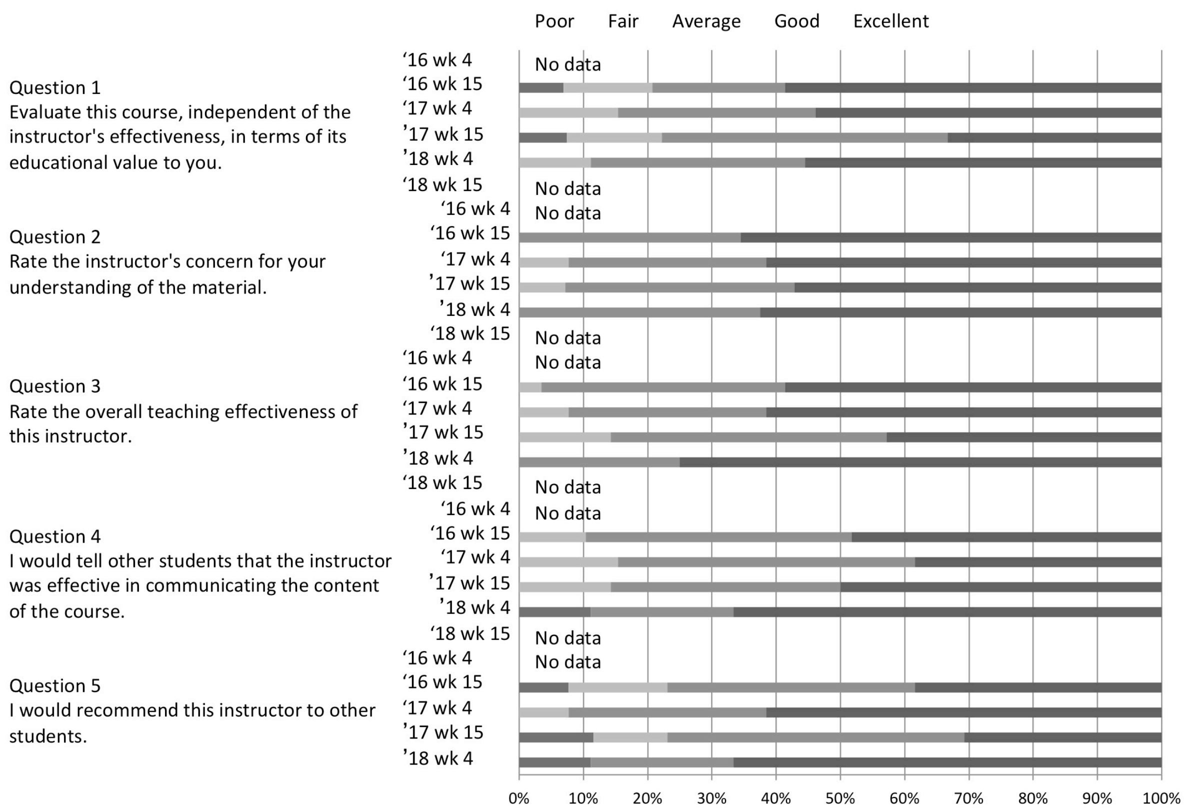
| Final grade | Spring 2016 (N=22) | Spring 2017 (N=28) | Spring 2018 (N=29) |
|---|---|---|---|
| A | 9 | 20 | No data* |
| B | 8 | 8 | ND |
| C | 5 | 0 | ND |
| F | 0 | 0 | ND |

* No date, ND: Final grades for the Spring 2018 course offering were not available at the time of publication.

Figure 3 presents a summary of student satisfaction for Spring 2016, Spring 2017, and Spring 2018 collected using an anonymous, online course evaluation administered via SurveyMonkey during the fifth week of the course and administered by the institution during the fifteenth week of the course. For Spring 2016, the first assessment was performed during the fifteenth week of the course. The rate of response (N=10) was less than half of the full course enrollment (N=22), and therefore an additional assessment conducted after week four was included in Spring 2017 and Spring 2018. The data from the fifteenth week of the course are not available for Spring 2018. Five questions were included in the assessments. The first three questions – assessing the quality of the course independent of the instructor; the instructor's concern for students; and the overall teaching effectiveness of the instructor – are required by the institution. The fourth and fifth questions – tell other students about the instructor's communication skills; and recommends the instructor to other students – are required by Missouri state law.

As shown in Figure 3, for the fifteenth week of Spring 2016 the results for all five questions demonstrate a bimodal response – at least two students expressed great dissatisfaction with the course (i.e., scored 1, poor, or 2 for each question) and at least eight students expressed great satisfaction with the course (i.e., scored 4, or 5, excellent for each question). Although a limited sample size, the results from the first offering of this course indicate that at least some students were satisfied – perhaps even a majority when considering that more than half of the students elected to ignore or not-complete optional assignments to earn a higher grade (Table 2, above).

**Figure 3.** Results of student assessments conducted after the fourth and fifteenth week of the semester in Spring 2016, Spring 2017, and Spring 2018. Responses are reported normalized to one hundred percent. (Gray-scale corresponds left-to-right to Poor, Fair, Average, Good, and Excellence).




As shown in Figure 3, for Spring 2017 the same five questions were administered via SurveyMonkey after week four and administered by the institution during the fifteenth week of the course. The response rate (N=28) was equal to the full course enrollment (N=28) after the fourth week while the response rate (N=13) was significantly lower after the fifteenth week. Assessment of student satisfaction after the end of the course provides a better opportunity to determine overall performance of the course and the instructor, but the lower response rate may create significant bias in the results (i.e., with a greatly likelihood of a bimodal result). In contrast, results collected after only four weeks of class may fail to provide a level of reporting necessary to fully evaluate the entire course – although perhaps the performance of the instructor may be assessed after such a short period.

A comparison of the results from Spring 2017 with the results from Spring 2016 in Figure 3 yields an encouraging picture. The extreme dissatisfaction reported in Spring 2016 has disappeared from the results of Spring 2017. Furthermore, one could argue that perhaps the course "grows" on students if the "upward" shift in the scores from week 4 through week 15 is real (i.e., some of the averages trend "upward" across the five questions in Table 4). Also, it is interesting to note that the question related to the course (i.e., question 1) and the question related to reputation (i.e., question 5) show a few low scores after the fourth week while the other questions – related more to the instructor – are generally positive after the fourth week. Although a limited sample size, the results of student assessment from Spring 2017 indicate that a majority of students were satisfied with the course and the instructor. This may further be supported by the number of "A" grades earned in Spring 2017 (Table 2, above).

As shown in Figure 3, for Spring 2018 the same five questions were administered via SurveyMonkey after week four, and no results are available yet for week fifteen. First, the response rate (N=29) was equal to the full course enrollment (N=29) after the fourth week, and again, as discussed above, these results are useful but limited because they do not represent the full semester. A comparison of the results from the fourth week for Spring 2018 and the results from both Spring 2016 and Spring 2017 demonstrate a consistent pattern with a large number of students indicating a high degree of satisfaction while a few students reported very negative opinions about the course.

To supplement the numeric scores reported in Figure 3, representative "additional comments", edited to increase readability, have been provided in Appendix 2 for Spring 2016 and in Appendix 3 for Spring 2017 as examples of the types of "free responses" received from students. To aid in evaluation of the comments, similar comments have been grouped. For Spring 2016, Comments A through G may be viewed as "negative". Comment A is *ad hominem*, and likely reflects a general negative attitude of an individual student; comments of this type are to be expected, as differences in personalities are inherent in any group setting. Comments B and C reflect a strong negative reaction to the attempts by the instructor to leverage the flipped classroom to include active learning as part of face-to-face lectures. Comment D reflects a negative response to the use of available online materials and may indicate a negative reaction to the use of a blended format. Comment E, F, and G appear to be related to discomfort with the use of mastery learning and the use of a buffet of optional summative assessments used to assign a final grade. Comments H through K may be viewed as "positive". Comments H and I represent spontaneous praise and encouragement on the part of students who "enjoyed" the course. While comments of this type are encouraging, they should be viewed with skepticism as similarities in personalities may influence students to "praise" instructors with whom they "identify" [7]. One way to address the issue of "teacher preference" versus "course content" is to replicate the course at sister institutions with diverse faculty and diverse types of students [30]. Comment J provides a positive reception to flipped, blended, and mastery learning, and Comment K recognizes the efforts to promote active learning as part of face-to-face lectures.

Collectively, the data presented in Appendix 2 suggest that the approach being employed in, "Public Health for Environmental Engineers," shows promise and should be pursued further.

For Spring 2017 (Appendix 3), comments A through F may be viewed as "negative". Comments A, B, and C indicate that students became aware that "traditional lectures" as recorded in the required online media were not as "stimulating" as the active learning used during the face-to-face lectures; thus, while these can be viewed as a "negative" comment about blended learning, they more likely reflect an affinity for active learning. Comments D and E reflect frustration with mastery grading. The instructor is sensitive to the appearance of favoritism, and in future classes greater transparency is needed to allow all students to understand when waivers have been issued based upon individual circumstances. FERPA regulations may likely limit the ability of the instructor to address these concerns; nonetheless additional efforts will be applied in this area. Comment F reflects a valid concern about the use of a buffet of optional summative assessments used to assign a final grade. The instructor has attempted to address this issue through an adjustment in the grading rubric used to assign points for completion of partial activities associated with the term project. Comments G through P may be viewed as "positive". As described above when discussing comments H, I, and J in Appendix 2, the spontaneous praise of an instructor should be viewed with skepticism to avoid the conflating similarities among instructor and student personalities and true evaluation of content and delivery. Comments K and L provide a positive reception to active learning in the face-to-face lectures, and comments M and N provide a positive reception to mastery learning. Comment O indicates a positive reception to the use of a buffet of optional summative assessments used to assign a final grade demonstrating that while some students may be skeptical, other students may find the approach encouraging. Finally, comment P represents the type of reception that the instructor has hoped to achieve.

As outlined in the introduction of this paper, the "modern" field of "environmental engineering" has expanded significantly from the "ancient" practice of "sanitary engineering". The instructor has attempted to intentionally design, "Public Health for Environmental Engineers," to re-invigorate the "ancient" sub-specialization of "sanitary engineering" within the field of environmental engineering. The observation that at least one student would positively note this as part of a "free response" after the fifteenth week of class is strongly encouraging (albeit a limited response).

**Discussion**

Recently, there has emerged an urgent call to re-integrate public health training into the curriculum for environmental engineers. For example, Mihelcic and co-authors argued that environmental engineering and science in the 21st century benefits from, "understand[ing] the importance of historical perspective as we transition forward," [13]. In particular, students of "modern" environmental engineering need to learn from and build upon the work of "ancient" sanitary engineering including the period of the "Great Sanitary Awakening," which emerged in England in the latter half of the 1800s. The education of future environmental engineers is in the middle of a "tug of war" – being pulled at one end by the research agenda and being pulled at the other end by the necessities of practice. In the wake of the discovery of preventable public health threats in essential infrastructure systems – such as lead contamination in the drinking water of Flint, Michigan – Edwards and Pruden argued for, "overturning the research paradigm to … defend public welfare," [31]. Whether working globally to promote access to safe water, sanitation, and hygiene (WaSH) among peoples of developing countries or working locally to manage the risks associated with environmental determinants of health, there is clear value in teaching environmental engineers the fundamentals and practice of public health as part of interprofessional education (IPE) in environmental health practice [24].

To address the urgent need to re-invigorate the sub-specialization of "sanitary engineering", a new course was created entitled, "Public Health for Environmental Engineers." This article summarizes the course content, pedagogical approach, and the results of assessments of three offerings to a total of 79 students in the Spring Semesters of 2016, 2017, and 2018. The course included a blended format, a flipped classroom, mastery learning, and a buffet of optional summative assessments used to assign a final grade. The course content builds upon and utilizes available materials from 180.601.01 Environmental Health at The Johns Hopkins University [15] and REHS/RS Study Guide [16]. While some students resisted the blended format (i.e., "The professor gets paid a lot, and he shouldn't use available online materials for teaching. He should make us purchase a text book and cover it in lecture"), and other students resisted active learning in face-to-face lectures facilitated by a flipped classroom (i.e., "Complete abuse of power; the professor creates an environment that is not conducive to learning by forcing students to answer questions during discussion"), nonetheless a positive response was achieved from other students (i.e., "I learned a lot of practical environmental health information that I plan to use in practice"). The instructor noted that positive comments from individual students may be biased due to similarities in personalities among students and the instructor, and that separating the impacts of the instructor and the value of the course content may be achieved by replicating the course at sister institutions with different faculty and different students [30].

The instructor learned: (1) a substantial investment of time is needed to create a course using blended, flipped, and mastery pedagogy; (2) a buffet approach to summative assessment to assign a final grade creates both new opportunities and new challenges as compared to a more "traditional" grading scheme; and (3) hands-on term-length projects focused on the practice of learned skills significantly increases anxiety among some students and significantly increases excitement for the course among other students.

Future work should: 1) follow-up with students to identify the value of the course in their professional practice; 2) assess changes in student attitudes and beliefs from before and after the course; and 3) replicate the course at other institutions to demonstrate effectiveness independent of the personality of the instructor and with a variety of student types.

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## **Appendix 1.** The instructions provided to students to complete their first, online, blended, flipped, mastery exercise in "Public Health for Environmental Engineers".

Course: Public Health for Environmental Engineers
Unit: 0 Introduction to Blended, Flipped, Mastery Learning
Document: FYI

The objective of this unit is to familiarize students with the technologies used in this course, to aid students in creating a personal plan for success in this course, and to begin to establish peer-peer interaction among students.

By the end of this module, students should:

1) be able to access Canvas for course materials
2) be familiar with the vocabulary and concepts that differentiate classroom and online education
3) understand the concepts of 'adult learning' and 'mastery learning'
4) have, in mind, a plan for successfully completing this course
5) complete at least one discussion board assignment
6) OPTIONAL complete a discussion board assignment to evaluate the pro's and con's of MOOCs

Detailed instructions of REQUIRED exercises (NOTE: All required exercises must be completed before the deadline stated in the syllabus. The completion of all required exercises is necessary to earn a grade of 'C'. If you do not complete all required exercises before the deadline stated in the syllabus, you earn a grade of 'F' for the entire course.)

1) download the file entitled, 'vocabulary.doc'
2) read the following blog entries making notes about the vocabulary terms:
   a. Making the transition from classroom to online education
   b. The difference between online and on campus courses
   c. How to ace your online class
   d. NOTE: these three blog entries are available for download as PDF files from the folder entitled, 'copies of blog entries'
3) using your notes, complete the online vocabulary quiz entitled, 'Unit 0 REQUIRED vocab quiz' (NOTE: You may retake this quiz as many times as you wish before the deadline stated in the syllabus. You must achieve a 100% to complete the quiz and to earn a grade of 'C' for this

exercise. If you do not achieve a 100% before the deadline stated in the syllabus, you earn a grade of 'F' for the entire course.)

7) open the folder entitled, 'REQUIRED lecture'
8) listen to the MP3 files and review the accompanying Power Point slides available in PDF format. Each MP3 file is approximately 15 minutes in length. (NOTE: you may wish to listen to the audio at an accelerated speed. ALSO NOTE: URLs are provided in the accompanying Power Point slides for you to access online tools to complete your Learning Styles Inventory and your Myers-Briggs Personality Test)
9) complete the online quiz for the required lecture entitled, 'Unit 0 REQUIRED lecture quiz' (note: You should take this quiz ONE time. You will need to complete the required lecture BEFORE you take this quiz so that you have the information necessary to document your Learning Styles Inventory and your Myers-Briggs Personality Test.)
10) complete the required discussion board activity entitled, 'Unit 0 REQUIRED online introductions'
    a. you are required to complete TWO separate posts, which include the following:
    b. Post One: a brief introduction of yourself suitable for reading by the entire class that includes:
        i. (1 pt) your complete name and what you liked to be called;
        ii. (1 pt) your student status (i.e., full/part time, and field/major);
        iii. (1 pt) brief expectations for the course (i.e., I'd like to learn a lot, I'd like to earn an 'A', I'm taking this course because it's a requirement, etc);
        iv. (1 pt) what you'd like to learn from the course (i.e., the practice of environmental health, environmental regulations, etc);
        v. (1 pt) your plans for how to tackle a course that uses a blended format, a flipped classroom, and mastery learning plus a buffet of summative assessment opportunities for assigning a final grade; and
        vi. (1 pt) how you like to communicate online (i.e., email, Twitter, etc).
    c. Post Two: (1 point) at least one professional and encouraging comment in response to an introduction posted by someone else in the class.

Detailed instructions of OPTIONAL exercise:

1) complete the optional discussion board exercise entitled, 'Unit 0 optional MOOC article'
    a. search the popular press (The Chronicle of Higher Education is one good source) for a news story discussing the 'pros' and 'cons' associated with MOOCs (i.e., read about edX or Coursera or Udacity or others).
    b. You need to make TWO separate posts, which include the following:
    c. Post One: (10 points total) a brief summary of the article that includes:
        i. (1 point) article citation (publication name, article name, author, date of publication, page numbers, URL, etc)
        ii. (1 point) what is a MOOC
        iii. (1 point) what is one 'pro' of a MOOC
        iv. (1 point) what is one 'con' of a MOOC
        v. (6 points) a concluding statement that supports or refutes the statement, "I believe (or do not believe) that MOOCs will revolutionize learning in higher education because…" Cite specific examples from the story and reference any external citations employed in your summary (your statement should be less than 250 words).
    d. Post Two: (10 points total) at least one professional and thought provoking criticism of someone else's concluding statement (i.e., While I agree with your assessment, I believe you missed this important point… etc)

## **Appendix 2.** Representative students comments provided during assessment in Spring 2016.

A. He is very boring and annoying
B. Complete abuse of power; the professor creates an environment that is not conducive to learning by forcing students to answer questions during discussion.
C. It is not the right of the professor to force students to answer his questions during class.

D. The professor gets paid a lot, and he shouldn't use available online materials for teaching. He should make us purchase a book and cover it in lecture.
E. I think the idea of mastery learning is great, but students don't learn anything in your class. Spend more time on going over the course material and less time on the optional project discussion.
F. It's great that you do practical work, but educationally I think it is unacceptable to force student participation in a practical term project as the only possible way to get an A in the class.
G. The strength of the class is the online learning, but the weakness is that I didn't need to put much effort into the optional assignments and I could still get a B.
H. Best teacher I've ever had in regards to engaging the classroom; very profound ideas and ways of doing things.
I. The professor is very knowledgeable, organized, and engaging. The course material wasn't interesting to me, but he keeps me awake and involved.
J. I loved the mastery learning method and the flipped classroom. The optional lectures were also very helpful.
K. He got the class to open up and engage in discussion.

## **Appendix 3.** Representative students comments provided during assessment in Spring 2017.

A. Some of the online lectures were dull or outdated and could maybe be replaced.
B. Try to limit the online feel but that might be unavoidable.
C. The online lectures were not as good as the in class portion.
D. The grading policy is a weakness - it stressed me out so much that sometimes it made it hard to focus on the information I was learning instead of the quickest way to get through the quizzes.
E. The professor had a policy of failure for missing required classes, but it seemed like some students were missing, and he didn't notice. I'd like to see the policy enforced more evenly.
F. Make the term project mandatory; as an optional assignment some people didn't work very hard and others had to carry the workload.
G. I really appreciated the professor's positivity, I looked forward to class, and I feel like I learned a lot.
H. Great Professor! He definitely was helpful to work around our schedule and do his best to answer any questions. He really wanted us to succeed which is rare among professors.
I. Instructor was great at motivating the students and helping them succeed.
J. Your depth of knowledge on topics was very clear and it made class much more enjoyable knowing you could answer anything we asked.
K. The professor stimulated students to think by providing time to discuss thought provoking questions.
L. The professor does a good job of including distance students in conversations and keeps the class engaged.
M. I never took a course that was structured this way and I really enjoyed it. The minimum workload wasn't too much and there was room for the students to earn more if they wanted.
N. Course utilizes "mastery learning" effectively. Instructor did an exceptional job of relating material covered to practical use.
O. I liked the structure of choose which assignments you want to complete.
P. I learned a lot of practical environmental health information that I plan to use in practice.