TEACHING EPIDEMIOLOGY AT THE UNDERGRADUATE LEVEL:

CONSIDERATIONS AND APPROACHES

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Funding: There was no funding

Conflict of interest: none declared

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Abstract

The rapid growth in undergraduate public health education has offered an increasing number of undergraduate students training in epidemiology. Epidemiology courses introduce undergraduate students to a population health perspective and provide opportunities for these students to build essential skills and competencies such as ethical reasoning, teamwork, comprehension of scientific methods, critical thinking, quantitative and information literacy, ability to analyze public health information, and effective writing and oral communication. Taking a varied approach and incorporating active learning and assessment strategies can help engage students in the material, improve comprehension of key concepts, and further develop key competencies. In this commentary, we present examples of how epidemiology may be taught in the undergraduate setting. Evaluation of these approaches and others would be a valuable next step.

Keywords

epidemiology, teaching, undergraduate

Abbreviations

CEPH Council on Education for Public Health

Word count

Abstract: 124

Text: 3,918
Introduction

Undergraduate public health education has experienced rapid growth in the past decade, with colleges and universities offering an increasing number of undergraduate students degrees, concentrations, and certificates in public health (1) and creating joint five-year programs with masters of public health (MPH) programs (2). To illustrate, from 1992-2012, the number of institutions conferring undergraduate public health degrees rose from 45 to 176, and the number of public health degree completions skyrocketed from 759 to 6464 (3). By 2015, there were almost 11,000 bachelor degrees conferrals in public health, and by 2016 there were 90 accredited undergraduate public health programs (4). During this same period, public health was one of the top 10 fastest-growing undergraduate programs in the United States (3). This proliferation of undergraduate public health education has been driven by increased interest in public health and global affairs among undergraduate students and advocacy for public health instruction at the undergraduate level from both individuals and organizations, including the Institute of Medicine (IOM), the American Public Health Association (APHA), and various national initiatives such as Healthy People 2020 and the Educated Citizen and Public Health Initiative (3, 5).

Epidemiology, a standard track in MPH programs, is generally not offered as a standalone undergraduate major (3). Yet, introductory epidemiology is a critical component to undergraduate public health education and is one of three core courses recommended for all colleges and universities offering undergraduate public health degrees (6). Undergraduate epidemiology courses introduce students to concepts of population health and aim to train students in the same key concept areas presented in graduate settings, with some variation in the scope, depth and complexity of the material (2). Although teaching epidemiology at the
undergraduate level presents unique challenges, it also provides an opportunity to enhance undergraduate education through development of essential skills and competencies.

With the increase in undergraduate public health courses and programs, journals have dedicated entire issues or portions of issues to the discussion of undergraduate public health education (please see the series “Undergraduate Education for Public Health in the United States” in Frontiers in Public Health, June 2015 (7), and the American Journal of Preventive Medicine, 2008, Volume 35, Issue 3 (8)). Although several articles have discussed best practices in teaching epidemiology (9-14), most are focused on graduate-level instruction. There has been far less discussion of introductory epidemiology at the undergraduate level, despite the rapidly growing number of institutions providing epidemiology courses in this setting. Therefore, this article aims to provide a commentary on undergraduate epidemiology instruction by describing the skills critical to undergraduate education that an introductory epidemiology course can provide, presenting considerations for teaching epidemiology at the undergraduate level, and offering an approach to teaching undergraduate epidemiology that we, as instructors of introductory epidemiology courses, have found effective. The purpose of this article is to encourage a discussion of how instructors can successfully engage the increasing number of undergraduate students in this material, promote understanding of key concepts, meet key educational objectives, and provide a foundation for graduate education and employment.

What can introductory epidemiology course offer undergraduate students?

The goals of undergraduate public health education are different from those at the graduate level.

Graduate programs in public health specifically train students for careers in public health
research and practice. Undergraduate curriculum in epidemiology and public health, in general, aims to educate entry-level public health practitioners and research assistants and prepare students for graduate study in public health (15), as well as provide exposure to areas in public health and stimulate interest in the field (16). Public health instruction can play an important role in all undergraduate education, including liberal arts curricula, by building intellectual, practical, and problem-solving skills and encouraging social responsibility (5).

The literature on undergraduate education has enumerated specific skills that require development among students in these programs (5, 17), much of it based on the Liberal Education and America’s Promise (LEAP) framework of essential learning outcomes for undergraduate liberal arts education (18, 19). The four key areas for development for undergraduate public health education, described by the Association of Schools and Programs of Public Health (ASPPH), are understanding of human culture and the natural world, intellectual and practical skills, individual social responsibility, and application of knowledge and skills to solving complex problems in new settings (20). To achieve these essential learning outcomes, these articles emphasize the importance of development in several key areas, including ethical reasoning, teamwork to solve problems, comprehension of scientific methods, critical thinking, and quantitative and information literacy (5). Undergraduate public health students also require classroom opportunities to develop their research and critical appraisal skills (21), as well as competency in effective writing and public speaking. These skills will be critically important prior to entry into graduate programs and the work force.

The Council on Education for Public Health (CEPH) also describes nine foundational domains that are required for undergraduate public health majors and concentrations and two foundational competencies that students in these programs must demonstrate in preparation for careers in
public health (22). Broadly, the foundational domains for instruction emphasize an evidence-based, population health approach to addressing health issues and reducing health disparities through an understanding of:

- factors associated with health and disease and the methods and tools required to identify and evaluate these factors,
- science of human health and disease,
- characteristics of health systems globally and key dimensions of health care and policy,
- approaches to project implementation, and
- communication of public health information.

Public health coursework and other learning experiences should ensure that students graduate with the ability to (1) communicate public health information both in writing and orally to different audiences and (2) identify, analyze, and apply public health information. CEPH competencies for undergraduate public health education are fewer in number compared to CEPH competencies for graduate-level public health education and focus on communication and the understanding and application of public health information (22).

Coursework in introductory epidemiology can play an important role in both undergraduate public health and liberal arts education, as common learning objectives for this course help students develop many of the learning outcomes and foundational competencies described above (Table 1). With its emphasis on population health, health disparities and disease etiology, the field of epidemiology is inherently geared towards understanding how culture, social structures, and the environment influence health and informing approaches to promoting health and social justice. To this end, students of epidemiology are asked to consider population-specific factors
that influence morbidity and mortality and create health disparities that may be targeted to promote health for all. As the science of public health (23), epidemiology provides a toolkit for generating this empirical evidence through application of the scientific method. Through exposure to key aspects of epidemiologic research – formulation of a research question and hypothesis, selection of a study population and critical evaluation of study design, exposure and outcome measurement, and potential sources of bias – students are able to develop critical thinking and problem-solving skills. In formulating best methods for answering specific questions in public health, students are also asked to consider important ethical issues such as informed consent, confidentiality, and ensuring the safety and wellbeing of research subjects. These activities, along with calculation of measures of disease frequency and association foundational to epidemiology, also enhance ethical reasoning and information and quantitative literacy and provide the opportunity to identify and analyze public health information.

Epidemiology is a collaborative and multi-disciplinary field, where effective communication and teamwork is critical. Epidemiologists rarely work alone, and they are often expected to partner with others in public health (e.g., policymakers) to improve population health (23). Thus, epidemiology is introduced to students as a field that involves experts from a wide variety of areas, working in teams to conduct public health research. An introductory course in epidemiology can highlight this teamwork as an effective approach to solving public health problems and provide students opportunities to practice teamwork skills as they work together on class activities and assignments. In addition to highlighting collaborative interaction, epidemiology also requires interpretation and communication of results. Once an analysis is complete, an epidemiologist does not present prevalence estimates or odds ratios alone but accompanies these findings with a discussion of what the results mean. In an introductory
epidemiology class, students are generally asked not only to calculate an odds ratio, for example, but also explain what the odds ratio is telling us about the association between an exposure and an outcome. This aspect of the course further builds information and quantitative literacy and provides students opportunities to practice interpreting public health information and communicating information clearly and effectively to others.

Courses in epidemiology can also motivate thinking towards issues that have gained importance in fields of public health, including how public health practitioners approach and manage the “information age”, providing an introduction to data science and the explore the challenges of “big data” in biomedical disciplines. Furthermore, epidemiology at the undergraduate level provides an opportunity for students to approach and interpret the evidence (or lack thereof) of primary, secondary and tertiary prevention strategies underlying public health and clinical practice – a notable benefit for students interested in public health and the health professions. Additionally, epidemiology may contribute broadly to the Science, Technology, Engineering, and Math (STEM) disciplines, providing a foundation for data literacy and an appreciation for the impact (both positive and negative) of advances in technology and engineering on health across the world.

Considerations and approaches

In this section, we discuss approaches to undergraduate epidemiology instruction and assessment that aim to engage students with different interests and educational and professional goals and address the skills and competencies described by the CEPH and LEAP frameworks. These approaches are targeted broadly to undergraduate epidemiology courses that comprise students
with a pre-professional (e.g., pre-health, public health) and/or a more liberal arts focus (e.g., with a dual concentration in other subjects such as anthropology, social work, molecular biology, sociology, history, political science). However, these approaches may be adapted to different settings, specifically through tailoring content and examples to reflect situations students will encounter in these fields.

Using a range of teaching and assessment strategies in undergraduate epidemiology courses can encourage student comprehension and engagement in the material and help students develop needed skills and competencies. In these courses, instructors can introduce key epidemiologic concepts during class lectures and assess understanding through a midterm and final quiz but reinforce concepts, engage students, develop critical thinking skills, and evaluate material comprehension through other strategies. In our courses, we have incorporated case studies, a research proposal assignment, health topic presentations, and a study design debate into course assignments and activities (Table 1). Our overall approach aims to build comprehension through examples, using active teaching strategies, and encouraging engagement by striving to make the class relevant to all students.

Undergraduate epidemiology instruction should favor a conceptual rather than technical approach (5), with less emphasis on memorization of terms and formulas and greater emphasis on examples that illustrate concepts. This increases the likelihood that a broad range of students, particularly those with less quantitative focus, grasp the key concepts underlying the formulas and related calculations. When teaching epidemiologic concepts to undergraduate students, presenting historical case-studies and examples of current public health threats are particularly important, given that these students may not be exposed to content of this nature through other coursework outside of public health. If the course is not being offered to only pre-health
students, it has been suggested that these examples not be limited to traditional health and medicine (6), but also incorporate topics from other subjects that may be more familiar to the student. This will not only help illustrate the knowledge and skills they are learning in other coursework, but also improve comprehension and stimulate student interest through real-world application. Asking students to discuss or present examples of epidemiologic studies from outside sources may also provide context for what they are learning in class, improve critical thinking and presentation skills, hone information literacy, and build confidence.

Introductory epidemiology courses may be less successful if students passively sit through lectures and take exams that test their capacity for memorization. Material is most effectively presented through active learning strategies (24) such as inquiry-based learning opportunities that involve students in practical exercises that build real-world epidemiology experience, completed in small groups when possible (21). These group exercises allow students to consider how epidemiologic methods are used to answer specific questions through interaction with their classmates and objectively evaluate information and make decisions based on this information, which reinforces concepts introduced in lectures and provides an opportunity to hone students' ability to think critically and work in teams to solve problems. Working through the challenges of group projects can ready students for professional environments in a broad range of disciplines. It also gives students who may be less comfortable speaking up during lecture or less able to come up with answers or comments as quickly as other students the opportunity to participate in discussion around these concepts.

These teaching approaches can be applied through case studies and a research proposal assignment. The case studies provide students the opportunity to develop critical thinking skills by using epidemiologic principles discussed in lectures to evaluate and analyze information
provided and make decisions on how to proceed. For example, students may be given background information on a research question of interest, provided options for study approaches for discussion (e.g., different data sources, study designs), and then asked to critically evaluate this information and select the most effective approach to answering the question. The case studies have in-class and take-home components. Each case study begins with a description of a public health “situation” and a specific research question and then asks students to think through the problem in the same way a trained epidemiologist would by responding to questions posed in groups. Each student independently completes the second half of the case study questions as homework. The goal is to have students make connections between the concepts presented in class and a real-world epidemiologic example and develop critical thinking, problem solving, teamwork, and communication skills.

Students in our introductory courses also work in teams to write up a research proposal that addresses a specific health concern, assigned by the instructor or one of the students’ choosing. The aim of this exercise is for students to use the concepts taught in lectures and case studies to address several aspects of answering an epidemiologic research question. Over the course of three assignments, students are asked to identify potential negative health outcomes that could be evaluated and select one outcome of public health importance, develop a focused research question that can be evaluated and a hypothesis, define the study population, describe how they would measure the exposure and outcome, consider potential biases in their approach (along with ways they might mitigate these biases) and confounders, and suggest an approach for addressing the issue or directions for future research. As we move through the material in the course, the assignments require students to use this material and feedback from the instructor to continue to build their study. This gives students an opportunity to experience the complex and iterative
nature of epidemiologic research, understand ethical issues in research, revisit and synthesize the material introduced throughout the semester from a real-world perspective, and objectively evaluate information to form conclusions. Students are introduced to the logical steps of conducting research, but they learn that it almost always requires rethinking and revision of the study approach. For example, students may choose to use hospital records as the primary data source for their study, but then realize later that information on key confounders is not available in that data source. The aim is to give students an opportunity to apply the scientific method to answer an epidemiologic research question and build teamwork, problem-solving, critical thinking and appraisal, and communication skills.

Other active learning strategies include “teachback” opportunities, whereby students “teach” concepts presented in lectures back to the class (21). This can help students improve their critical appraisal and communication skills and understanding of scientific methods and also gives them an opportunity to consider any ethical issues that may arise in their studies such as threats to participant confidentiality and screening without treatment availability. In our courses, we provide teachback opportunities through a health topic presentation and a study design debate. Throughout the course, each student (or group) gives a short presentation on a health topic of interest from a media source of their choosing (e.g., a newspaper article) once during the semester. The presentations must answer three questions: What is the issue being discussed? What is the public health importance? How is epidemiology involved? The class is then invited to ask questions. These presentations provide students with the opportunity to engage a topic through basic research using a variety of media sources. Using current, real-life examples, students can illustrate the knowledge and skills they are learning in the course and critically evaluate and communicate health-related information presented in the media. This exercise also
engages students by demonstrating the variety of public health and epidemiology topics discussed in current news and allowing them to identify topics that are of particular interest to them, which can further engage them in the course. This exercise also hones health literacy and allows students to build communication and public speaking skills.

During the study design debate, students are separated into four groups based on study design: randomized controlled trial, cross-sectional, cohort, and case-control. The instructor acts as the health commissioner, interested into conducting a study to answer a specific health question (e.g., Does eating a Mediterranean diet reduce risk of stroke?). Each group is provided with a description of each study design, which also includes study population, time period, and how the exposure and outcome is defined, all with substantial flaws. Students discuss the strengths and limitations of all four study designs in groups, and then each group tries to convince the health commissioner that its study design is preferable over others, with a focus on bias, generalizability, and resources needed. It has proven a fun, interactive exercise that reinforces concepts taught in lectures and encourages critical thinking, builds communication skills, and improves understanding of study design through lively discussion.

Approaches for ensuring comprehension of key epidemiologic concepts and building academic and practice skills can only be successful if students are actively involved in the course. Engagement in the material can be improved by emphasizing the broad applicability of epidemiology (6) – from its role in understanding disease etiology to its use as a tool to form an evidence base for public health programming and policy – to the students’ own academic and professional goals. Students can be further engaged by highlighting the skills that students will have after completion of the course that may also be relevant in a variety of professional settings.

For example, the ability to interpret and assess the validity of health-related findings is important
for clinicians choosing treatment for their patients. Understanding the basics of study design and conduct is useful for research in many fields outside of public health such as economics and sociology. Introductory epidemiology courses can also stimulate interest in epidemiology and public health by introducing public health practitioners and researchers to the class and letting students hear about their experiences and the diverse academic and career opportunities in the field (25) through guest lectures and a career panel. Through this experience, students can understand the broad range of topics and careers within the field and appreciate the relevance of the material to their own career goals.

In our own courses, we invite 4-5 individuals with a wide variety of public health careers and backgrounds to visit our class; describe their current positions in public health, education, and career trajectories; and answer questions from students. We also invite guest lecturers to present examples of applied epidemiology in the context of methodological principles a few times during the semester. These lectures can take the form of an introduction to an epidemiologic field or a health condition. The purposes of these lectures are to reinforce epidemiologic principles, provide relevant examples to place the concept in context, and introduce an area of public health epidemiology. These two approaches allow students to better understand how epidemiologic concepts are used in practice and become familiar with career and academic opportunities in public health. It also introduces students to the idea that career paths are rarely linear, and that successful public health practitioners have diverse backgrounds and experiences. Feedback from our students suggests that these activities particularly useful for helping them connect to the material and develop their own interests in public health.

Although several of the approaches discussed above may be more suitable to smaller class sizes (e.g., under 35 students), they can be adapted to larger classes. For example, if a large class has a
series of smaller recitation sections in addition to lectures, health topic presentations, case studies and study design debates may be a useful activity during recitation. In larger class environments without a recitation, instructors may take advantage of digital technologies to explore case studies and other activities through online forums. Additionally, larger courses can effectively “flip” the classroom by assembling the students into groups of 3-5 during class to discuss case studies, debate study design and work collectively on an activity that required reading or preparation prior to class. This approach will stimulate discussion and connect students in what would otherwise be a traditional lecture setting.

Conclusions

As public health curriculum gains additional traction at the undergraduate level, it is important that instructors consider how they can engage and prepare these students for future study and careers in public health as well as other related disciplines. The multifaceted nature of public health education – which generally includes courses in public health theory, social determinants of health, environmental health, policy, epidemiology, and biostatistics – demands consideration of how to most effectively teach each of these aspects of public health to a burgeoning undergraduate audience. This commentary provides a preliminary discussion of approaches to teaching undergraduate introductory epidemiology. Although we present some examples of how epidemiology may be taught in the undergraduate setting, there are certainly other effective methods of undergraduate epidemiology instruction. Evaluation of the effectiveness of these and other approaches for developing essential skills and competencies in this growing student population would be a useful next step.
Table 1. Learning Outcomes and Competencies Addressed by Common Undergraduate Epidemiology Learning Objectives and Proposed Instructional Approaches

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<th>Course components</th>
<th>ASPPH undergraduate public health learning outcomes</th>
<th>CEPH foundational competencies</th>
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<td></td>
<td>Knowledge of human cultures and the physical and natural world</td>
<td>Intellectual and practical skills</td>
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<td><strong>Learning objectives</strong></td>
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<tr>
<td>Describe history and role of epidemiology in public health</td>
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<tr>
<td>Use epidemiological approaches to define and measure health problems across defined populations</td>
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<tr>
<td>Critically evaluate data sources</td>
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<tr>
<td>Describe and critically evaluate basic study designs</td>
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<tr>
<td>Apply epidemiological criteria needed to establish and interpret cause and effect relationships</td>
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<td>Describe key ethical issues to conduct of studies</td>
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<td>Communicate findings orally and in writing</td>
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<td>Health topic presentation</td>
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<td>Study design debate</td>
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ASPPH = Association of Schools and Programs of Public Health, CEPH = Council on Education for Public Health
Acknowledgements

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We would like to thank Dr. Bernadette Boden-Albala for her thoughtful review of the manuscript.

Conflict of interest: none declared.
References


