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Applied Epidemiology and Public Health: Are We Training the Future Generations Appropriately?

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Abstract

To extend the reach and relevance of epidemiology for public health practice, the science needs be broadened beyond etiologic research, to link more strongly with emerging technologies and to acknowledge key societal transformations. This new focus for epidemiology and its implications for epidemiologic training can be considered in the context of macro trends affecting society, including a greater focus on upstream causes of disease, shifting demographics, the Affordable Care Act and health care system reform, globalization, changing health communication environment, growing centrality of team and transdisciplinary science, emergence of translational sciences, greater focus on accountability, big data, informatics, high-throughput technologies (“omics”), privacy changes, and the evolving funding environment. This commentary describes existing approaches to and competencies for training in epidemiology, maps macro trends with competencies, highlights an example of competency-based education in the Epidemic Intelligence Service of Centers for Disease Control and Prevention, and suggests expanded and more dynamic training approaches. A re-examination of current approaches to epidemiologic training is needed.

Keywords

education; epidemiology; genomics; globalization; medicine; public health; training; translational research

We write this commentary at a time of transition as new technologies and associated data streams, changing health care systems, and broader societal transformations are changing the

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landscape of public health (1, 2). In fact, by the time of publication of this commentary, there will have been a major shift in the US government that will likely have consequences for public health and health care. We focus on these broad trends and their implications for epidemiology, a core science underpinning public health. We address and describe these trends and explore their consequences for the training of epidemiologists. We provide evidence that an immediate need exists to acknowledge these trends and to respond with changes in the training of epidemiologists.

Epidemiology has a rich history of successes in determining underlying causes of diverse health problems and in assessing the effectiveness of preventive approaches (3). In part, because epidemiology is a relatively new field of science, much effort during recent decades has been directed at development and refinement of research methods; less attention of the academic community has focused on how to effectively apply epidemiologic principles in public health settings (sometimes called consequential epidemiology (4–6)). Instead, different entities, primarily governmental, within the applied sector have taken the lead.

Understanding the similarities and differences between what has been termed classical epidemiology and more applied approaches is helpful. In part, the distinction lies in the setting, academia or public health practice. Classical epidemiology is rooted in a methodological foundation that focuses on descriptive epidemiology, etiologic research, and causal inference (7). Particularly in cancer epidemiology, requests have been made to extend epidemiologic training and practice to a more translational focus (e.g., more interdisciplinary and engaged in driving policy and practice) (8, 9).

For public health practice and policy, this extended reach of epidemiology includes a greater emphasis on applied science. The domain of applied epidemiology has been characterized by the following five core purposes (10): 1) synthesis of results of etiologic studies as input to practice-oriented policies; 2) description of disease and risk-factor patterns as information to set priorities; 3) evaluation of public health programs, laws, and policies; 4) measurement of patterns and outcomes of delivery of public health services and health care practice; and 5) communication of epidemiologic findings effectively to health professionals, different decision makers, and the public. When compared with classical epidemiology, particularly as carried out in academia, those involved in applied epidemiology face a greater sense of urgency, use data covering a range of quality, and more often learn the methods of epidemiology on the job through experiential learning (11).

Looking to the future, training in epidemiology, whether classical or applied, should be placed in the context of macro trends affecting society. Macro trends reach nationally and globally, involving changing demographics, economic factors, technology changes, and legal, political, or social conditions. In work sponsored by the American College of Epidemiology, a team of senior epidemiologists recently identified the following 12 macro trends that are affecting the practice of epidemiology (12): 1) greater focus on upstream causes of disease; 2) shifting demographics; 3) the Affordable Care Act or health care system reform; 4) globalization; 5) changing health communication environment; 6) growing centrality of team and transdisciplinary science; 7) emergence of translational sciences; 8) greater focus on accountability; 9) big data or informatics; 10) emerging high-

throughput technologies (“omics”); 11) privacy changes; and 12) evolving funding environment (Table 1) (13–17).

HOW EPIDEMIOLOGY IS COMMONLY TAUGHT IN ACADEMIC TRAINING PROGRAMS

Training in epidemiology occurs both in formal settings where a degree is conferred (e.g., universities) and in less formal settings for a range of public health and clinical practitioners (e.g., public health agencies and elsewhere). In academic settings, epidemiology is now widely taught at multiple levels of competency achievement, ranging from introductory courses at the undergraduate and entering public health levels to early professional training to advanced series of courses that cover the principal study designs, more advanced designs, and complex analyses. Different entry-level texts that are widely used, some with multiple revisions (e.g., the textbook by Leon Gordis, *Epidemiology*, 5th edition (18)). At the entry level, emphasis is placed on using laboratory exercises to engage students with data and problem-solving; such laboratory exercises date to early curricula, such as that implemented by Wade Hampton Frost, the founding Chair at the then Johns Hopkins School of Hygiene and Public Health. Although similarity exists among entry-level courses, which are typically grounded on one of the introductory texts, much greater heterogeneity is noted at more advanced levels. In fact, only one principal advanced methods text is available to support such courses at present, *Modern Epidemiology*, a book firmly rooted in classical epidemiology (19). Certain schools (e.g., the Johns Hopkins Bloomberg School of Public Health) have established separate applied and methods series of courses in epidemiology. In Australia, a masters degree (MPhil) is conferred to foster development of field epidemiology (20).

COMPETENCIES AND APPROACHES FOR TRAINING APPLIED EPIDEMIOLOGISTS

Training programs for applied epidemiology are grounded in a set of competencies that are commonly defined as a cluster of related knowledge, skills, and abilities important for job activity performance in a defined setting and can be measured against well-accepted standards (21). Training in epidemiology and public health has benefitted from competency-based education, which has helped to shape existing educational programs and guide future planning (22). To be effective, competencies must be revisited on a regular basis.

Practitioner-oriented, on-the-job training in applied epidemiology is even more heterogeneous in teaching methods. Formal and highly developed training programs, such as the Epidemic Intelligence Service (EIS), are taught with a very short didactic portion and also with a longer, supervised, experiential learning component. Beyond such formal programs as EIS, training can be largely experiential with supplemental short courses. Because some epidemiologists in public health practice lack extensive, formal training in epidemiology, numerous short courses are available, ranging from brief online programs to longer in-person trainings.

MAPPING EXISTING TRAINING PROGRAMS TO MACRO TRENDS

To assess how well current training frameworks are linked with major societal and scientific shifts, we mapped the 12 macro trends against five sets of competencies (Table 1). Although this is not a comprehensive list, the mapping identified a number of critical gaps. Four of the macro trends are almost absent from current competency sets, including emergence of team or translational sciences, greater focus on accountability, growing availability of big data or informatics, and emerging high-throughput technologies (“omics”).

These gaps are present despite considerable new knowledge and material to support training in these areas. For example, regarding team or transdisciplinary science, we know that nearly every public health problem is complex (23), requiring attention at multiple levels and among many different disciplines. Team approaches that bring together diverse disciplines and organizations have the potential for developing new and creative ways of designing and implementing studies and addressing public health concerns. An epidemiologist can often play a vital role within a transdisciplinary team; epidemiologists skilled in adapting traditional epidemiologic methods for application in diverse fields (e.g., engineering, organizational science, urban planning, or public policy) can be particularly effective team members (24).

TRAINING EPIDEMIOLOGISTS IN THE EPIDEMIC INTELLIGENCE SERVICE

Here, we consider the example of the EIS program from the Centers for Disease Control and Prevention (CDC), which has needed to maintain relevance in the training of its fellows during the more than six decades of its existence. As such, it is unique for its longevity and its grounding in a model that is fundamentally unchanged, but sufficiently flexible to adapt to ever-changing contexts since its founding. Recognizing the importance of field-based education, EIS is a long-standing fellowship program built on a foundation of learning and training through service during the competitive two-year applied epidemiology training program. When EIS was started in 1951 in response to the threat of biological warfare during the Korean War, the program included 22 physicians and one sanitary engineer (25). A typical EIS class today would include approximately 80 officers with 75% physicians and PhD-level scientists, and 25% veterinarians and other health professionals. In their rigorous on-the-job training, EIS officers participate in approximately 250 field investigations each year in the United States and around the world to identify causes of disease outbreaks, recommend prevention and control measures, and implement strategies to protect persons from injury, disability, illness, and death.

To achieve proficiency in applied epidemiology, EIS uses *Competencies for Applied Epidemiologists in Governmental Public Health Agencies* developed by CDC and the Council of State and Territorial Epidemiologists (13). These competencies were developed within the framework of the Core Competencies for Public Health Professionals, a product of the Council on Linkages Between Academia and Public Health Practice (15).

EIS uses eight domains reflecting skill areas within public health and three tiers representing career stages for public health professionals in determining EIS competencies.

Competencies selected within each of eight domains (e.g., analytical or assessment skills) reflect needs of the EIS program and align to 10 core activities for learning (CALs) that EIS officers must complete during training. Certain competencies map to the 12 macro trends affecting the future needs of epidemiology (Table 1). One macro trend that EIS is incorporating into training is big data or informatics, reflecting CDC's 2014 surveillance strategy to collaborate with principal public health surveillance stakeholders, customers, and partners to improve CDC health surveillance activities and investments (26). In 2013, the EIS program modified the CAL requiring officers to evaluate a public health surveillance system. To ensure that EIS officers understand real-world use of the informatics components of surveillance, they are asked to include information regarding data capture (who sent the information and how), data management (data standards used for coding and transmission), information quality, system quality, and user experience. This required additional didactic training incorporated early in the fellowship.

EIS will soon have its first full complement of detailed 6-month evaluations from EIS classes based on using the modified CAL. The data will be used in assessing the uptake of current competencies, the extent to which EIS officers become fully competent on a competency, and how CAL completion aligns with the competencies. These data will help determine if previously included competencies can be deleted and if new competencies are needed to meet the changing needs of public health. There is particular interest in the competency needs concerning the macro trends of informatics, globalization, and upstream causes of disease given recent global outbreaks. For example, by using information gained from surveillance systems evaluation, CDC expects to report that more EIS officers are able to use data from new sources and help create automated case adjudication and reporting to decrease user error and improve surveillance. One relevant EIS project was completed in 2013 by using surveillance data to estimate the numbers of children with autism spectrum disorder living in different areas of the United States. The current approach, requiring trained clinicians to review text from medical and educational records, is labor-intensive and costly. The new method seeks to deploy a machine-learning approach to instantly classify records as indicative of autism. If successful, this approach would allow for faster data reporting while saving money (27). Thus, experience with the EIS demonstrates that a program can evolve in a data-driven fashion that responds to trends in needed competencies.

MORE EXPANDED AND DYNAMIC APPROACHES FOR TEACHING EPIDEMIOLOGY

By contrast, instruction in epidemiology in academic institutions largely remains grounded in the definition of the science as describing occurrence of disease and finding causes of disease. At the basic level, emphasis is placed on indicators of population health and straightforward applications of the cross-sectional, case-control, and cohort designs. Analytical methods and discussions of bias are centered on the didactically useful but simplistic two-by-two tables. Even a quick consideration of the macro trends indicates that far more is needed (Table 1). For example, these trends indicate the need for a new generation of epidemiologists who are equipped to address emerging data streams, big data, and informatics in different contexts focusing on determinants of disease risk, use of

surveillance systems for tracking upstream cases and policy-related determinants, evaluation of interventions addressing population health, and assessment of the use of tailored therapies and clinical outcomes (e.g., outcomes from health reform efforts).

Training epidemiologists to work in these emerging contexts poses challenges for the educational enterprise, adding new domains and new competencies to classical and applied epidemiology. As epidemiologic research and application are redefined during the coming decades through the technology revolution, new communication methods, and big data, we will need to retain much of the long-established didactics of epidemiology, but with an overlay that prepares epidemiologists to work in the team context requisite for dealing with ever larger data sets and more complex public health problems.

A new series of competencies and associated curriculum must be elaborated; we need to get started on this task. To best serve public health practice, a need exists to recruit and train a new type of epidemiologist, particularly because a single epidemiology training program, academic or otherwise, cannot meet all contexts that arise with the macro trends highlighted here. As has been the case historically, future epidemiologists need strong quantitative backgrounds. For persons trained in university settings, trainees should be encouraged to cross departments and disciplines, thus allowing them to begin to apply the tenets of team-based, transdisciplinary science (28). For some programs, two different tracks for training may be useful (traditional/etiologic and applied). For epidemiologists already in practice, there is a need for continuing education programs to highlight the macro trends and the skill sets needed to be an epidemiologist in a changing world.

Macro trends predicts that academic epidemiologic research will increasingly shift toward use of large data bases that incorporate diverse data streams and new types of questions that are not directly related to etiology. One concern is whether these types of macro trends will further the divide between a new academic epidemiology, building on classical epidemiology of decades past, and applied epidemiology.

In contrast, certain problems within the domain of applied epidemiology will be unchanged; outbreaks and disease clusters will persist as will the need for collection and interpretation of surveillance data. Several of the macro trends are rooted in surveillance data and involve identification of needed modifications and improvements to existing systems. Shifting demographics are first noted through surveillance; identifying upstream causes of disease, uptake and analysis of electronic records, privacy changes, and loss of funding represent both the strengths and weaknesses that surveillance can offer for epidemiologic data. For solving some problems, the basic two –by-two table will remain sufficient and readily applied by practitioners. For other problems, whether being addressed in the field or by researchers, approaches will be needed that take full advantage of all data available. For example, community resilience, an issue of concern for practitioners, is multi-dimensional as is exploration of the genetic basis of disease, a topic of interest to academic researchers.

For certain application problems, the two-by-two table will remain relevant, but for other high-dimensional problems it will not. Thus, to an extent and for certain applied epidemiologists, a need will exist to have both the long-established competencies of a

practice orientation and the competencies called for by the macro trends reflecting a more modern view of epidemiology.

SUMMARY AND CHARGE TO THE FIELD

A major challenge for epidemiologists, whether academic or applied, is to continually improve population health, even as the backdrop for epidemiology changes. Macro trends that have driven this commentary are certain to be predictive of changes to come, likely at an accelerating pace. To sustain the relevance and impact of epidemiology, our training curriculums, continuing education programs, and recruitment of those who will serve in both the academic and applied sectors needs to be continually refined. In our view, we are not moving quickly enough and concerns that we raise are not adequately recognized by the diverse stakeholders involved in training epidemiologists. We hope that this commentary will accelerate that recognition and lead to collaborative efforts to reorient epidemiologic training to more fully align with current and future trends in technology and society.

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Abbreviations

CDC	Centers for Disease Control and Prevention
CALs	core activities for learning
EIS	Epidemic Intelligence System

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Table 1
Actions and Educational Competencies Corresponding to Macro Trends Affecting Applied Epidemiology

Macro Trend ^a	Actions for the Field	Example Educational Competencies (source ^b)
1. A greater focus on upstream causes of disease	<ul style="list-style-type: none"> Develop the capacity to translate science into action in venues ranging from local to global, especially policy translation. Articulate how epidemiologic skills and research, survey and surveillance data can play a role in systems modeling studies. Develop methods to link social and demographic characteristics into existing data systems (e.g., electronic health records). 	<ul style="list-style-type: none"> Consider the role and influence of sociobehavioral factors (including community, political, social, family, and individual behavioral factors) in health risks and health status (EIS/CSTE). Participate in translation of public health policies into epidemiology roles in programs or plans (EIS/CSTE). Assess cultural, environmental, and social justice influences on the health of communities (DrPH). Influences policies, programs, and services external to the organization that affect the health of the community (e.g., zoning or transportation routes) (CL).
2. Shifting demographics	<ul style="list-style-type: none"> Improve the capacity to work with persons and groups with different backgrounds and life experiences and to carry out research in a culturally meaningful and appropriate way. Identify the role of cultural factors in disease etiology and prevention. 	<ul style="list-style-type: none"> Design data collection tools to capture information needed to assess health disparities (EIS/CSTE). Use knowledge of specific socio-cultural factors in the population (EIS/CSTE).
3. The Affordable Care Act and health care system reform	<ul style="list-style-type: none"> Collaborate with clinicians and health services researchers to identify key research and policy questions along with measurement needs. Continue to broaden the range of populations considered in epidemiologic research to encompass those within health care systems. Consider the balance of cost versus value in healthcare system strategies 	<ul style="list-style-type: none"> Describe knowledge of privacy laws to protect confidentiality, including Health Insurance Portability and Accountability Act and applicable state and local privacy laws (EIS/CSTE). Determines community health status and factors influencing health in a community (e.g., quality, availability, accessibility, and use of health services; access to affordable housing) (CL).
4. Globalization	<ul style="list-style-type: none"> Develop and enhance cross-national partnerships to enhance the infrastructure, quality, and scope of epidemiologic practice and research. Carry out multi-national studies that take advantage of the wide exposure gradients that might exist. Develop new approaches for epidemiologic training for low- and middle-income countries. 	<ul style="list-style-type: none"> Describes public health as part of a larger inter-related system of organizations that influence the health of populations at local, national, and global levels (CL). Understand the global, cultural, and social context of health problems and how these influence the conduct, interpretation, and dissemination of research and intervention studies (ACE).
5. The changing health communication environment	<ul style="list-style-type: none"> Develop new methods for epidemiologic studies, surveys and surveillance that take advantage of new technologies (e.g., smart phone surveys or GPS tracking). Integrate training in epidemiology more fully with other disciplines concerned with communication and dissemination (e.g., communication or marketing). 	<ul style="list-style-type: none"> Use information technologies and communication tools necessary to support epidemiologic investigations and surveillance (EIS/CSTE). Identify audience, methods, and content for communication of epidemiologic findings (EIS/CSTE). Tailor surveillance information content and periodicity of dissemination for specific audiences and their uses (EIS/CSTE).

Macro Trend ^a	Actions for the Field	Example Educational Competencies (source ^b)
	<ul style="list-style-type: none"> Work with biostatisticians and quantitative methods experts from other fields to develop new research methods, study designs and data analysis procedures. 	<ul style="list-style-type: none"> Evaluates strategies for communicating information to influence behavior and improve health (e.g., uses social marketing methods, considers behavioral theories such as the Health Belief Model or Stages of Change Model) (CL).
6. The growing centrality of team and trans-disciplinary science	<ul style="list-style-type: none"> Encourage academic institutions to promote career advancement that rewards team science. Develop metrics within funding mechanisms to evaluate and ensure effective reviews of transdisciplinary science. Identify the role of epidemiology along the research continuum, from basic to applied research. Develop publication metrics that more accurately and fully convey scientific contributions from team science. 	<ul style="list-style-type: none"> Demonstrate professional interpersonal, interdisciplinary, cross-disciplinary, and multidisciplinary communication (EIS/CSTE). Apply theoretical and evidence-based perspectives from multiple disciplines in the design and implementation of programs, policies, and systems (DrPH). Demonstrates the value of a diverse public health workforce (CL).
7. The emergence of translational sciences	<ul style="list-style-type: none"> Develop partnerships between epidemiologists and practitioners in community or clinical settings. Develop new courses on translational science. Continue to develop and improve analytic tools (e.g., systematic reviews and evidence portals) that link research and practice. 	<ul style="list-style-type: none"> Employ evidence-based communication program models for disseminating research and evaluation outcomes (DrPH).
8. A greater focus on accountability	<ul style="list-style-type: none"> Develop a culture of accountability and health influence by facilitating practice of reproducing studies, sharing and translation. Understand the role of public reporting of health systems data related to quality and safety. Understand the role of data stewardship in making data accessible and useable by the public. 	<ul style="list-style-type: none"> Influence others to achieve high standards of performance and accountability (DrPH).
9. The growing availability of big data and informatics	<ul style="list-style-type: none"> Support wider use of language processing and other data exploration or analytical approaches used in computer sciences. Support the harmonization of data sets and the creation of study repositories. Correct ontologies are needed for this purpose. Develop epidemiologic capacity for integration of data from basic, clinical, environmental, social, and population sciences. 	<ul style="list-style-type: none"> Use relevant data and information sources within and outside the public health system (EIS/CSTE). Experience working with large datasets (ACE).
10. Emerging high-throughput technologies ("omics")	<ul style="list-style-type: none"> Articulate the opportunities and challenges presented by genomic and other "omic" research and how epidemiology and epidemiologists can help meet those challenges. Foster collaboration between epidemiologists, biostatisticians and other quantitative methods experts to improve methods to quantify the risk and predictive abilities of genomic and other "omic" discoveries. 	<ul style="list-style-type: none"> Explain how genetics and genomics affect disease processes and public health policy and practice (EIS/CSTE).

Macro Trend ^a	Actions for the Field	Example Educational Competencies (source ^b)
11. Privacy changes	<ul style="list-style-type: none"> • Work with those building clinical data enterprise warehouses to anticipate privacy and consent concerns related to future uses of data and specimens for epidemiologic research. • Develop privacy and confidentiality systems that balance the rights of persons with the needs of society. 	<ul style="list-style-type: none"> • Apply procedures (policies) and technical means (security) to ensure the integrity and protection of confidential information in electronic files and computer systems (EIS/CSTE). • Incorporate privacy laws into study design to protect confidentiality, including Health Insurance Portability and Accountability Act and applicable state and local privacy laws (EIS/CSTE). • Develop tools that protect the privacy of individuals and communities involved in health programs, policies, and research (DrPH). • Comprehend basic ethical and legal principles pertaining to the collection, maintenance, use and dissemination of epidemiologic data (MPH).
12. The evolving funding environment	<ul style="list-style-type: none"> • Encourage the leveraging of existing resources. • Make the case more effectively for the necessity and consequences of epidemiologic research. • Link training programs more closely with research programs to more efficiently use resources. 	<ul style="list-style-type: none"> • Evaluate the performance and impact of health programs, policies, and systems (DrPH). • Establish goals, timelines, funding alternatives, and strategies for influencing policy initiatives (DrPH).

^aThe first two columns are adapted from Brownson et al. (12)

^bSources: CDC/CSTE Competencies for Applied Epidemiologists in Governmental Public Health Agencies (CDC/CSTE) (13); Doctor of Public Health Core Competency Model (DrPH) (14); Council on Linkages between Academia and Public Health Practice, Core Competencies for Public Health Professionals (CL) (15); American College of Epidemiology, Workshop on Doctoral Education in Epidemiology (ACE) (16); Core Competencies for Public Health Professionals (MPH) (17);