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Training the Twenty-First Century Cancer Epidemiologist

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Abstract
To assess and advance training of twenty-first century cancer epidemiologists, the National Cancer Institute (NCI) sought to obtain a snapshot of the cancer epidemiology training landscape by conducting a survey across academic institutions and cancer centers, focusing on four key training areas driving current cancer epidemiology research ("drivers"): (1) collaboration, (2) novel methods/technologies, (3) multilevel analysis, and (4) knowledge integration. Complementary to the survey, we conducted a portfolio analysis of active NCI-funded training grants. In the present report, we provide our findings from this effort and contribute to the on-going conversation regarding the training of next-generation cancer epidemiologists. Analyses and insights gained from conversations with leaders/educators across 24 academic institutions/cancer centers and the portfolio analysis of training grants echoed contemporaneous conversation that cancer epidemiology training must adapt to meet the needs of the changing research environment. Currently, with the exception of novel methods/technologies, cancer epidemiology trainees receive the majority of their training in collaboration, multilevel approaches, and knowledge integration/translation either informally, ad hoc, or not at all; exposure to these identified drivers varied considerably by institution, mentor, and other external as well as internal factors.

Keywords Cancer epidemiology · Training · Education

Introduction

Epidemiologists have traditionally conducted research in the areas of disease etiology and burden, risk estimation, prevention, and causality. In addition, they aspire to advance the tools of study design, methodology, and analysis [1]. In 2011, Jonathan Samet remarked that epidemiology had entered "a new era [marked by] technology-driven change, big data, and genomics" [2]. Moreover, epidemiology has expanded to include areas such as assessment of therapy outcomes, health disparities, and cancer survivorship research. As a result of an initiative by the National Cancer Institute (NCI) to advance cancer epidemiology research, Khoury et al. [3] proposed eight recommendations to transform epidemiology practice

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and research to meet the needs and challenges of twenty-first century medicine and public health. At the core of this transformation lies the need for a pedagogical shift to adequately prepare the next-generation of cancer epidemiologists. As discussed elsewhere (4), this shift is necessitated by the recognition that at least four "drivers" are influencing the future of cancer epidemiology: (i) collaboration and team science; (ii) methods and technologies; (iii) multi-level analyses and interventions; and (iv) the need for knowledge management, synthesis, and translation of basic, clinical, and population science research findings, which we term knowledge integration [4]. Contemporaneously, Brownson et al. [5] echoed similar themes when, on behalf of the American College of Epidemiology, they sought to identify macro-level trends that are changing epidemiologic research and practice.

The engagement and participation of academia and training institutions are essential to modify the current curricula to train the next-generation of epidemiologists. To advance the dialog on training twenty-first century epidemiologists and identify key action items, we obtained a snapshot of the training landscape for cancer epidemiologists, including those supported by NCI-funded training grants. We (i) surveyed training in the four key drivers described above in the curriculum of selected training institutions (schools of public health, cancer centers, and other training programs) and (ii) conducted a portfolio analysis of active grants funded by the NCI, concurrent with the timeline of the survey. In this paper, we provide our findings and contribute to the on-going conversation regarding training of the next-generation of cancer epidemiologists. We further discuss insights shared by current educators interviewed. As the cancer epidemiology research milieu is shifting, partially ushered in by rapidly evolving technologies, "big data," and other macrotrends, cancer epidemiology training programs should evolve and adapt to modern needs to ultimately prepare the future's research workforce to reduce the burden of cancer in the population.

Methods

Survey of Training Institutions

To survey the landscape of doctoral and post-doctoral training curricula for cancer epidemiologists, we developed a set of key questions centered on training in the four key research driver areas previously identified by Lam et al. (5): (i) collaboration and team science; (ii) exposure to and adoption of novel methods and technologies; (iii) multi-level approaches to epidemiologic research and intervention (e.g., integration of biological, behavioral, group, and macro-social factors); and (iv) application of knowledge integration methods and concepts (management, synthesis, and translation of scientific findings) to inform evidence-based recommendations/policies and to accelerate translation of scientific findings into public health impact. The survey also solicited additional training competencies that may influence the future of cancer epidemiology. We piloted the survey with four institutions before finalizing the questions. The final survey instrument (Appendix 1) was approved by the Office of Management and Budget (OMB #0925-0046-08). We compiled a list of academic institutions and cancer centers with training components in cancer epidemiology and consulted leading experts in the field to ensure our sample was broadly representative. The final interview list comprised of 28 academic institutions and cancer centers (Appendix 2).

The survey was conducted between December 2014 and March 2015. We sent an email invitation to an identified director/faculty member of each institution with a description of the project's purpose and an invitation to participate in the survey. We also attached an electronic copy of the survey for preview, a consent form, and relevant publications. In the invitation email, we offered to conduct the survey via telephone conference. The survey interviews ranged from 45 min to 1 h in length. We abstracted relevant information for analysis from the interview notes.

We performed descriptive statistical analyses using chi-square to compare differences on key elements. For survey questions #5–#7 (Appendix 1), we asked interviewees to rank the degree of importance with respect to several areas of interest from 1 to 4, with 1 being most important. For data analysis of responses to these two questions, we grouped the rankings into three ranking categories to correspond to the numeral ranking of 1 to 4, respectively. Group 1 was comprised of items ranked #1, group 2 was comprised of items ranked #2 or 3, and group 3 was comprised of items ranked #4. We also obtained the average of the ranking ($Rank_{avg}$) of each question by summing the individual ranking and dividing by the total number of interviewees who responded to the question. Statistical significance was considered at a p value < 0.05.

Portfolio Analysis of Funded Training Grants

We performed a portfolio analysis of all active NCI grants receiving funds in May 2015, to be concurrent with the timing of the survey. We used the following search terms: epidemiology, epidemiologist, epidemiologic, epidemiological, "cancer prevention," "population science(s)," and training, train, course, courses, coursework, and "career development" to identify funded training grants of relevance to the survey.

We first reviewed abstracts and full applications to identify grants that were related to cancer epidemiology. From the identified set of grants, three reviewers coded the grants with respect to the following characteristics: (i) cancer epidemiology specific; (ii) components of cancer epidemiology (including epidemiology courses); (iii) collaboration (indicators of cross discipline exposures in training proposal); (iv) multilevel approach (e.g., research proposed to integrate at least two different determinants like genes and environment); (v) novel methods/technologies (research proposed to incorporate or develop new methods/technologies, e.g., an assay); and (vi) knowledge integration (research proposed contained elements of knowledge management, knowledge synthesis, or knowledge translation). Additional information obtained included where training takes place (academia, cancer center) and area of formal training (epidemiology, medicine, biostatistics, etc.)

Results

Survey

Of the twenty-eight institutions identified for our survey, 26 responded to our invitation (93% response rate). Interviews were conducted shortly after each responded. We excluded two institutions (University of Hawaii and Stanford University) from the final analysis because neither had a formal or semi-formal training program related specifically to cancer epidemiology. Table 1 presents selected characteristics of the 24 (13 academic institutions and 11 cancer centers) institutions and the overall distribution with respect to training in the key training driver areas of interest. Of the 24 institutions, the proportion of academic (54%) and cancer centers (46%) was similar, 67% ($n = 16$) had an NCI-funded training grant, and this was similarly distributed between the types of institution (p value = 0.08). Overall, our survey showed that 67% of the institutions provided formal training (e.g., courses with credits) for novel methods and technologies, whereas only a small minority provided formal training in the areas of collaboration/team science (13%), multilevel approach (17%), and knowledge integration (29%). Trainees across the institutions were typically exposed or trained informally (e.g., journal clubs) in the areas of collaboration/team science (88%) and multilevel approaches (63%). Compared to the other key "drivers," most of our interviewees (54%) reported no exposure to the area of knowledge integration (e.g., systematic review/meta-analysis courses).

Table 2 presents data for formal training in key drivers by selected characteristics. Eighteen institutions (75%) reported at least one or more type of formal training in key drivers and ten (42%) institutions reported having formal training in at least two key drivers. The proportion of academic institutions (12/13, 92%) offering formal training in at least one driver was significantly higher than the proportion of cancer centers (6/11, 54%; p value = 0.03 vs. academic institutions). While 81% of institutions with NCI-supported training grants provide their trainees with formal training in one or more key drivers ($n = 13$ of 16), only 63% ($n = 5$ of 8) of those without training grants do so; no statistical significance was observed (p value = 0.32).

We asked the interviewees to rank the importance of obtaining formal training in the four key drivers when considering how to have a successful career in epidemiology 5–10 years into the future, and the answers varied considerably (Fig. 1). Forty-six percent of those interviewed ranked formal training in novel methods and technologies to be the most important with an average ranking of 1.81. Both collaboration/team science ($\text{Rank}_{avg} = 2.95$) and translation of scientific findings ($\text{Rank}_{avg} = 2.91$) were ranked to be of lesser importance than other drivers. Regardless of the driver, the majority of interviewees felt that training in all of the four areas was very important.

When we asked the interviewees to rank the importance of five different identified assets for a successful career in cancer

Table 1 Overview of collaboration, novel technology, multilevel approach, and knowledge integration training at 24 US institutions

Type of institution	n^a (%)	Training grants[b], n (%)	Core areas of practicum							
			Collaboration, n (%)		Novel methods/ technologies, n (%)		Multilevel approach, n (%)		Knowledge integration, n (%)	
			Formal[c]	Informal[d]	Formal[c]	Informal[d]	Formal[c]	Informal[d]	Formal[c]	Informal[d]
Total	24	16 (67)[e]	3 (13)[e]	21 (88)[e]	16 (67)[e]	21 (88)[e]	4 (17)[e]	15 (63)[e]	7 (29)[e]	4 (17)[e]
Academic	13 (54)	9 (69)[f]	2 (15)[f]	12 (92)[f]	10 (77)[f]	13 (100)[f]	4 (31)[f]	7 (54)[f]	5 (38)[f]	2 (15)[f]
Cancer center	11 (46)	7 (64)[f]	1 (9)[f]	9 (82)[f]	6 (55)[f]	8 (73)[f]	0 (0)[f]	8 (73)[f]	2 (17)[f]	2 (17)[f]

[a] Two interviews (University of Hawaii Cancer Center and Stanford University) were excluded due to lack of a training program

[b] Has an NIH training grant (T32 and/or R25)

[c] Formal courses include class/seminar for which course credit is given

[d] Informal training includes journal clubs, seminars, brown-bag sessions, ad-hoc working groups

[e] Percentage based on total interviews ($n = 24$)

[f] Percentage of within sub-categories

Table 2 Formal training in key drivers by type of institution and training grant status

	Type of institution		Training grants	
	Academic (n = 13)	Cancer centers (n = 11)	No (n = 8)	Yes (n = 16)
# of formal trainings in key driver				
0	1	5	3	3
1	5	3	3	5
2	5	3	2	6
3	2	0	0	2
p value[b]	0.03		0.32	

[a] Formal training: providing course credit

[a] p value zero versus ≥ 1 formal course

epidemiology, the top three ranked assets were communication skills, supportive mentors, and innovativeness (Fig. 2). The vast majority ranked having leadership/management ($Rank_{avg} = 3.77$) and self-assessment skills ($Rank_{avg} = 4.45$) fourth or fifth in overall ranking. Innovativeness, as in extending beyond the traditional approaches, was ranked highest in level of importance ($Rank_{avg} = 1.73$). Regardless of the rankings, most interviewees indicated during the interviews that all the assets were important.

When we asked the interviewees to rank the degree of importance for mentors to obtain enrichment skills in 3 of the 4 driver areas (collaboration, multilevel and translation), the responses were comparable across areas with no distinct choice emerging as particularly important compared to others (Fig. 3). Table 3 presents additional areas that the interviewees identified as vital for a successful cancer epidemiology research career looking forward 10 years.

Training Grants

Table 4 presents the selected characteristics of the NCI training grants that we reviewed (date of last search, May 2015). Using our search criteria, we identified a total 39 training grants for pre- and post-doctoral candidates at various

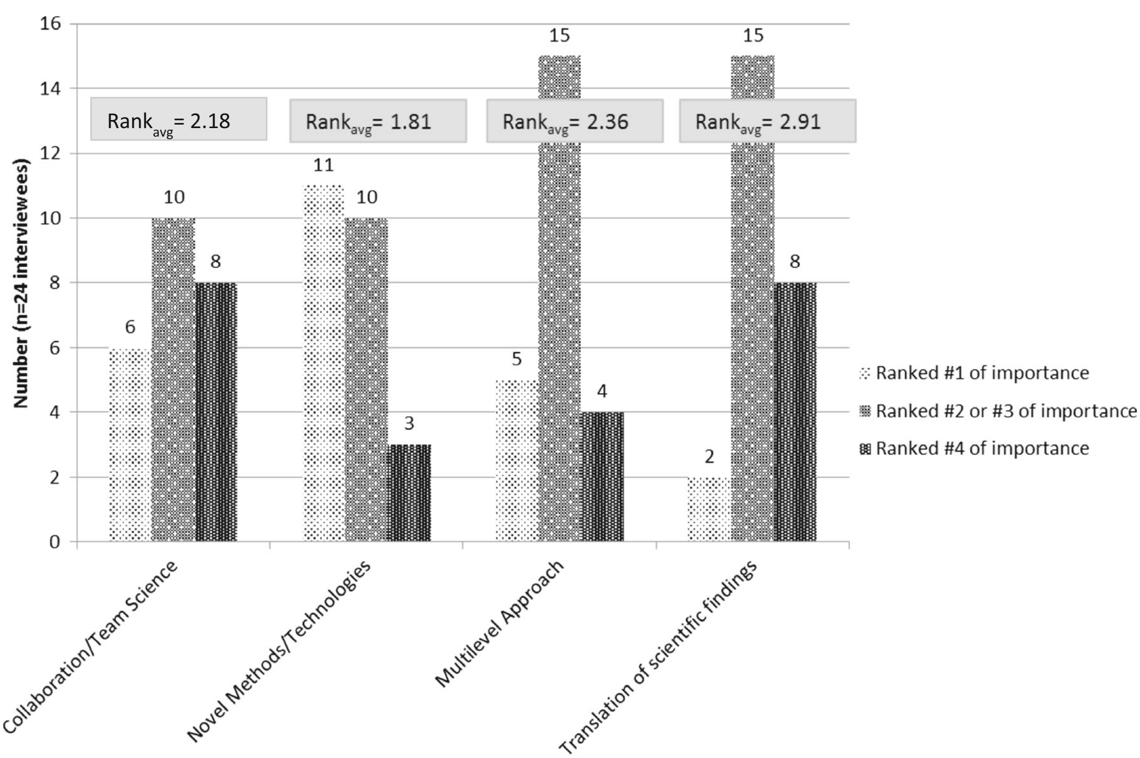

Fig. 1 Degree of importance in obtaining formal training with respect to skills or abilities for a successful epidemiology degree 5-10 years into the future (n=24 interviewees)

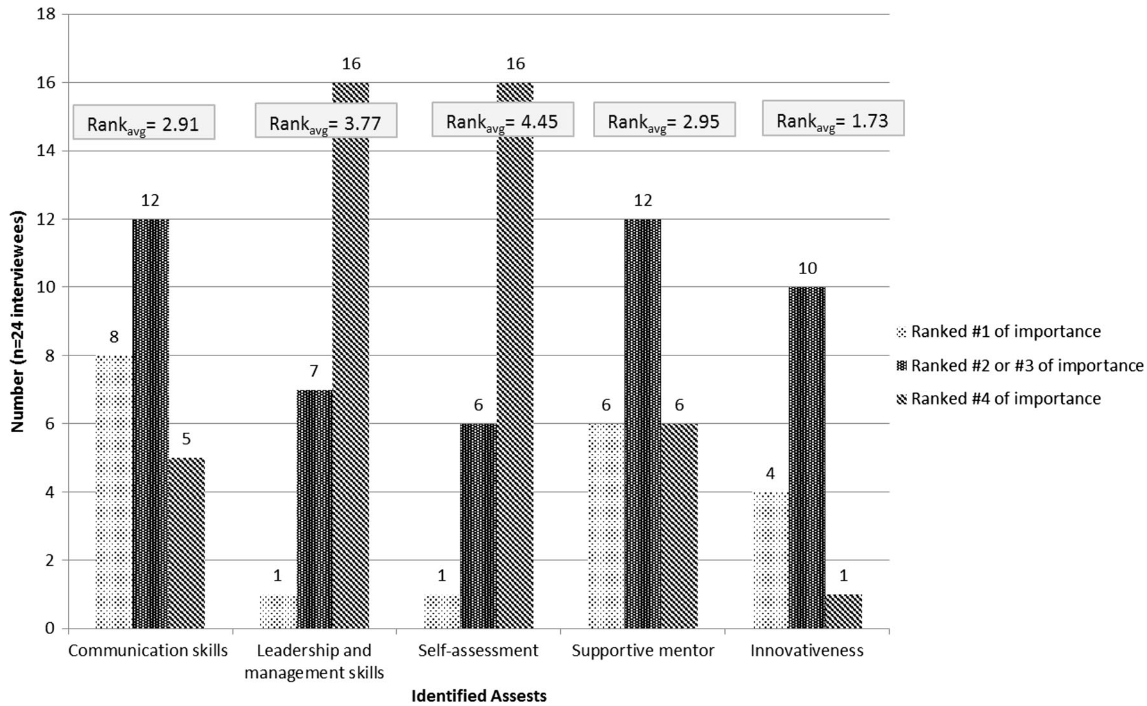

Fig. 2 Degree of importance of the identified assets to a successful career in cancer epidemiology ($n = 24$ interviewees)

academic institutions with cancer epidemiology training programs. Training grants were distributed across several mechanisms (F31, K05, K07, K08, K22, K23, K24, R25, and T32, Table 4). A description of each mechanism can be found at the Center for Cancer Training's website [6]. The most common mechanisms used for cancer epidemiology training are the Cancer Research Education Grants Program (R25, $n = 9$) and the Institutional Research Training Grant (T32, $n = 9$). The R25, in particular, provides support for educational activities that complement and/or enhance the training of a workforce to meet the nation's scientific needs. This mechanism permits proposals designed to support curriculum or methods development, skills development, and research experiences. The T32 provides support to institutions to develop or

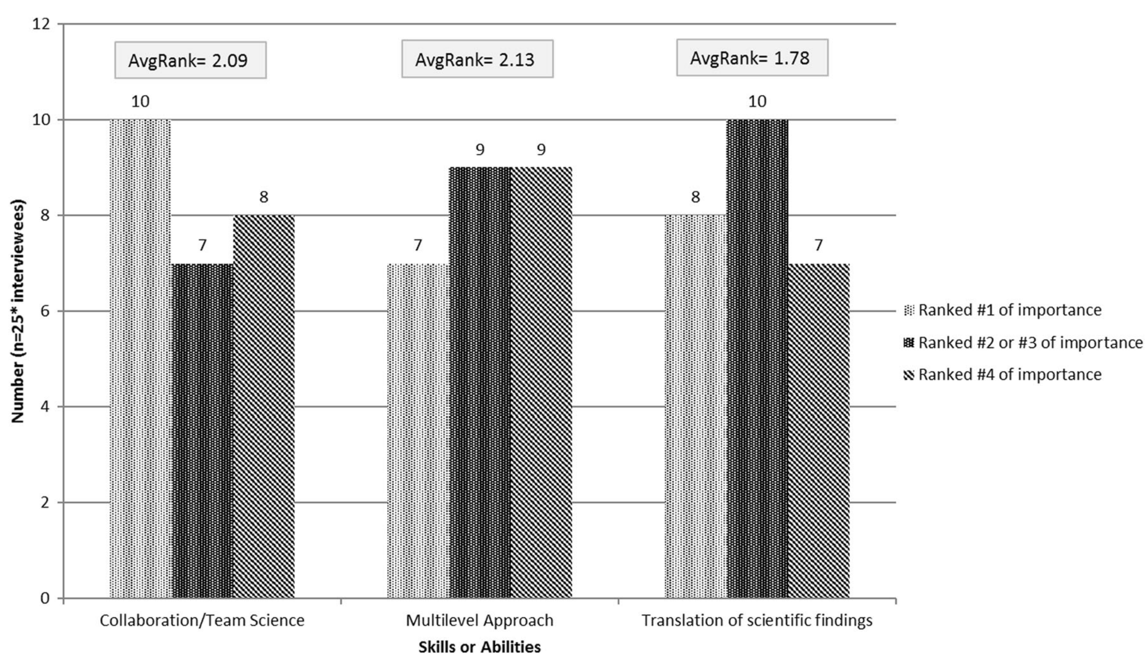

Fig. 3 Degree of importance for mentors to obtain enrichment skills with respect to selected areas ($n = 25^*$ interviewees). Asterisk means one institution provided separate rankings from two interviewees

Table 3 Additional skills (beyond standard curriculum) vital for successful cancer epidemiology career

Communication via:
Grant writing
Manuscript review
Data integration (e.g., from electronic medical records, disparate databases, etc.)
Deeper epidemiology methods knowledge for:
Data collection and harmonization
Bioinformatics
Data science/analytics
Management (grant/project/personnel)
Precision medicine—understanding methods/study design
Understanding of cancer biology/etiology

enhance research training opportunities for both predoctoral and postdoctoral fellows.

Per the search criteria, a considerable proportion of training grants (74%) included epidemiology as part of the training modules, either in their curriculum or hands-on research component. Forty-four percent of cancer epidemiology-related training (non-physician) was primarily supported by three mechanisms, R25 ($n = 7$), K05 ($n = 5$), and K07 ($n = 5$). Of the nine T32 grants, only four contained a specific focus on cancer epidemiology. The remaining five grants had a course or seminar related to epidemiology. In contrast to the survey findings, the majority of training grants described training features that foster collaboration (74%), multilevel approach (85%), and translation (97%) as part of their training curriculum. Conversely, novel technology/method training was not included as a core area of practice in 92% of grants and none incorporated concepts of knowledge integration in their curriculum.

The distribution of disciplines of trainees varied considerably. These disciplines included cancer epidemiologist, genetic/molecular epidemiologist, physician focused on cancer epidemiology (physician + cancer epidemiologist) and physician with general focus on epidemiology (physician + epidemiologist). The most funded disciplines were cancer epidemiologists (44%; $n = 17$), followed by physician desiring additional expertise in epidemiology (31%; $n = 12$). The T32 funding mechanism appears to be the primary source used to train physicians who are interested in additional training related to either cancer epidemiology or general epidemiology (n-7).

Discussion

The field of human cancer research is ever-evolving, and the pace of change is increasing. As it evolves, training of the cancer epidemiology workforce must also evolve to meet new challenges. Recent publications have discussed trends in and influences on training in disciplines such as cancer epidemiology [7], epidemiology [5], and cancer prevention [8]. Uniquely, the present report provides an overview of the contemporary landscape of cancer epidemiology training specifically focused on four drivers, or core areas, of interests: (1) collaboration, (2) novel methods/technologies, (3) multilevel approaches, and (4) knowledge integration. With the exception of novel methods/technologies, few of the surveyed institutions provided formal training for these drivers in their curriculum. Rather, their cancer epidemiology graduate students typically received training in collaboration, and even less so multilevel approach and knowledge integration, informally through journal clubs/seminars or ad hoc via research projects. Training in these latter three areas therefore varied considerably by institution, mentor, and other external and internal factors. Formal or informal training for knowledge integration, as measured in part through credited courses in systematic review/meta-analysis, was lacking in most curricula based on our survey findings and was not documented in the NCI epidemiology-focused funded training grants.

One of the greatest differences observed between the survey findings and portfolio analysis was with respect to training in novel methods/technologies. In the survey, formal training for novel technologies/methods was ranked top amongst the skills/abilities required for a career as cancer epidemiologists, 67% offered formal and 88% offered informal training in this area, and 88% of those surveyed ranked importance of formal training #1, 2, or 3 versus the other drivers. In contrast, this area was rarely described in training grants (8% specified this area as a training component). The reasons for this are unclear, but they could reflect an implicit understanding in the training grant context that this type of coursework will necessarily be offered to those preparing for twenty-first century cancer epidemiology research careers.

For training in knowledge integration (e.g., meta-analysis training), a somewhat murkier picture emerged. Of those surveyed, 29 and 17% offered formal and informal training, respectively. On the other hand, none of the training grants had knowledge integration included as a core area of practice. The term knowledge integration, described by us [9] as management, synthesis, and translation of scientific findings, is not used interchangeably with translation, but 97% of training grants described translation as a core area of practice. In addition, 68% of those surveyed ranked formal training in translation either #1, 2, or 3 versus the other areas, indicating that formal training in translation is seen as relatively important. These mixed results are likely contributed to by the non-universal use of the term "knowledge integration," but nonetheless indicate that training in translation is seen as a core area of practice for future cancer epidemiologists.

Of survey respondents, 88% indicated they had collaboration training that occurs in non-formal settings, over 70%

Table 4 Portfolio analysis of training grants funded by the National Cancer Institute (active grants May 2015)

Mechanisms	No. of grants (*n*)	Active grants (*n*)	Discipline				Epi-focus		Opportunity for epidemiology or MPH courses		Core areas of practicum: Means of collaboration		Novel methods and technology		Multi-level approach		Knowledge integration		Translation	
			Cancer epidemiologist (*n*)	Geneticor molecular epidemiologist (*n*)	Cancer and physician epidemiologist (*n*)	Physician epidemiologist (*n*)	Yes (*n*)	No (*n*)	Yes (*n*)	No (*n*)	Yes (*n*)	No (*n*)	Yes (*n*)	No (*n*)	Yes (*n*)	No (*n*)	Yes (*n*)	No (*n*)	Yes (*n*)	No (*n*)
F31	3	1	3	0	0	0	3	0	1	2	1	2	0	3	2	1	0	3	3	0
K05	5	3	2	0	1	2	5	0	5	0	2	3	0	5	4	1	0	5	5	0
K07	6	2	3	1	0	2	5	1	4	2	6	0	0	6	5	1	0	6	6	0
K08	4	0	1	1	0	2	3	1	2	2	4	0	1	3	3	1	0	4	3	1
522	1	0	1	0	0	0	1	0	1	0	1	0	1	0	1	0	0	1	1	0
K23	1	0	0	0	0	1	0	1	0	1	0	1	0	1	1	0	0	1	1	0
K24	1	0	0	0	0	1	1	0	0	1	0	1	0	1	1	0	0	1	1	0
R25	9	2	5	1	3	0	7	2	6	3	8	1	1	8	7	2	0	9	9	0
T32	9	2	2	0	3	4	4	5	7	2	6	3	0	9	9	0	0	9	9	0
Total (n)	39	10	17	3	7	12	29	10	27	12	29	10	3	36	33	6	0	39	38	1
(%)			44	8	18	31	74	26	69	31	74	26	8	92	85	15	0	39	97	3

ranked importance of formal collaboration training #1, 2, or 3 versus the other drivers, and 74% of the training grants described a component of collaboration and/or collaborative research for trainees. Findings for multi-level approach training were very similar to those for collaboration training in both the survey and training grant analysis. Training in these two key areas is more often gained through the process of working with mentors and collaborators on various research projects. Given this, the responses to the question about assets for a successful career in cancer epidemiology were not surprising; 75% ranked a supportive mentor as #1, 2, or 3 in the list of five skills. Communication skills and innovativeness were ranked similarly. Clearly, all three need to be in place for success as a cancer epidemiologist, and many surveyed had a hard time selecting which of these skills would rank the highest. Since survey respondents likely work with many trainees, some of whom are not focused on cancer epidemiology, we generalize that their views on these skills may apply more broadly across other scientific disciplines.

Given that most of the training in the drivers is occurring informally and 25% of the institutions surveyed had no training in any of the drivers (38% without vs 19% with training grants), the importance of external/contextual factors becomes even greater. For example, an epidemiology department's proximity to other complementary departments may facilitate cross-training in multiple disciplines and thus foster skills in collaboration/team science, novel methods/technologies, and other drivers. In an environment surrounded by other departments or disciplines, trainees may also be exposed to potential mentors via a broad range of scientific seminars and easy access to their primary mentor's nearby collaborators. However, some of those surveyed suggested that an apprenticeship during the postdoctoral years may be more ideal for trainees to gain exposure and skills to facilitate collaborative research, though little to no formal training for postdoctoral trainees was outlined by the groups we interviewed. Postdocs typically had access to courses for graduate students, but requirements were minimal. We postulate that without multiple, supportive cross-discipline mentors, it may be challenging for some trainees to acquire skills for career success when they are meant to do so informally.

While a period of apprenticeship at some point in graduate or postdoc years can help a trainee expand skills, the training framework for cancer epidemiology should continue to be grounded in classic epidemiologic concepts of study design, methods, and analysis. Epidemiologic concepts will allow trainees to differentiate associations from causation, and some have proposed a novel pedagogic approach to epidemiology instruction for a broader group of public health scientists (12). We note that for success in cancer epidemiology research, a foundational knowledge of cancer biology, pathology, and/or basic biology will also further elucidate observed associations between an exposure X and cancer Y. Awareness of connections may lead the trainee epidemiologist to pursue a novel hypothesis or think about the question differently. Beyond the biological underpinnings of carcinogenesis, a training program that provides a foundational knowledge of social/structural determinants may further provide cancer epidemiologists with the tools to incorporate a multilevel approach in practice. Thus, we recommend that training programs consider incorporating multilevel training into current courses if they do not already do so.

There is also a growing sentiment that the training curriculum for epidemiologists, cancer prevention researchers, and health-related practitioners should provide core competencies focused on interdisciplinary leadership, communication, and teamwork [10–12]. These topic-specific training modules are not confined to the cancer epidemiology only and trainees in other disciplines may equally benefit from the inclusion of these core skills. Training future leaders may require a more deliberate approach to establish a baseline foundation for knowledge and skills for collaborative research, particularly as the cancer research enterprise becomes a more integrative model and increasingly reliant on technologies, big data, and cross-communication between experts (e.g., population-based scientists, biologists, geneticists, and bioinformaticians). The survey respondents reflected some of this thinking when asked what additional skills, beyond the standard curriculum, they saw as critical for the twenty-first century cancer epidemiologist. They listed things that can be taught in a variety of settings, including communication skills like grant writing and manuscript review, data integration skills, deeper knowledge of epidemiology methods, management skills, understanding of precision medicine methods/study design, and understanding of cancer biology/etiology. They suggested that this training would occur through the graduate and postdoctoral years, combining class time with hands-on work. Again, it would seem that strong mentoring would be a key to a trainee's success; the mentor or several multi-disciplinary mentors would help provide diverse perspectives, identify areas of strength for a trainee, along with areas for improvement.

Previously, Dr. Harold Varmus, former director of NIH and NCI, and colleagues recommended that the education of graduate students should be supported with training grants and fellowships and not with research grants [13]. Our survey and portfolio analysis suggest that institutions that have an NCI-funded training grant offer more formal training with respect to the identified drivers and are also more apt to provide cross-disciplinary education as part of the training process. It is foreseeable that these training funding mechanisms, when fully utilized, may facilitate the development of a pedagogic experience with supplemental exposures in key skills/concepts/methods to train twenty-first century cancer epidemiologists.

The present report was derived from an effort to engage educators in assessing the training of tomorrow's cancer epidemiologist. Our findings, derived by a survey and a grant portfolio review, are limited in scope and are not reflective of an expansive landscape for cancer epidemiology or all of epidemiology training. While we made great efforts to broadly include academic and cancer centers in the United States that we know to provide training to cancer epidemiologists, it is not an exhaustive list. Moreover, the responses to the survey questions may reflect the individual perspective(s) of the interviewed educators. Notwithstanding these limitations, this report is the first to our knowledge to provide an overview of cancer epidemiology training and the corresponding funding landscape. Our survey findings and portfolio analysis, coupled with insights shared by the educators, echo certain sentiments previously published by our colleagues [5, 8, 11, 14] and to a great extent are relevant and applicable to other disciplines beyond cancer epidemiology. The twenty-first century cancer epidemiology research enterprises will be led by a workforce that must be trained to be nimble and adaptive to advanced technologies and understand the large data generated from those technologies, epidemiological principles/concepts and methods, cancer biology, and statistical methods. Moreover, cancer epidemiologists will need to be even more collaborative than ever, as team science may provide the platform to understand and meet the challenges posed by the complexities inherent in cancer.

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