Are Biostatistics Students Prepared to Succeed in the Era of Interdisciplinary Science? (And How Will We Know?)

Melissa D. BEGG and Roger D. VAUGHAN

Recent years have seen an increasing emphasis on interdisciplinary approaches to solving problems in biomedical and public health research. While the concept is not new, interest in interdisciplinarity is expanding, as reflected by the growing body of literature on interdisciplinarity, the increasing prominence of teams of researchers working collaboratively, and the intense interest on the part of public and private granting agencies to fund interdisciplinary research proposals. The reason most often cited for the mounting interest in interdisciplinarity is that we are addressing health problems that are highly complex; and complex problems require complex approaches to achieve solutions. To produce investigators who can succeed in interdisciplinary environments, training programs must impart an understanding of the rationale behind these approaches, how they are distinct from more traditional approaches, and the skills to be successful members and leaders of interdisciplinary teams across a wide range of health research initiatives. In this article, we discuss: definitions for multidisciplinary, interdisciplinary, and transdisciplinary science; the rationale for interdisciplinary collaboration; a review of interdisciplinary requirements in training programs in biostatistics and the sciences; and implications for the training of future biostatisticians.

KEY WORDS: Biostatistics education; Curricular reform; Training program.

1. INTRODUCTION

The scientific literature is increasingly characterized by a stronger and more visible emphasis on interdisciplinary and team science approaches to solving problems in biomedical and public health research (Weeks, Wallace, and Surott Kimberly 2004; Committee on Facilitating Interdisciplinary Research 2005; Wuchty, Jones, and Uzzi 2007; Baethge 2008). This focus is reflected in a number of ways: the growing body of literature on interdisciplinarity, the increasing prominence of teams of researchers working collaboratively, and the intense interest on the part of public and private granting agencies to fund interdisciplinary research proposals. One of the explanations often offered for the growing attention to interdisciplinarity is that we are addressing health problems that are highly complex; and more complex problems require more complex approaches to achieve solutions, often requiring the combined efforts of diverse teams of scientists from multiple disciplines (Zerhouni 2003). To succeed as an investigator in this new, interdisciplinary environment, biostatisticians need to understand the rationale behind these new approaches, how they are distinct from more traditional approaches, and how the field of biostatistics can work to advance and support these approaches across a wide range of health research initiatives. In this article, we discuss: definitions for multidisciplinary, interdisciplinary, and transdisciplinary science; the rationale for interdisciplinary collaboration; a review of current approaches to interdisciplinary training for biostatistics doctoral students; a recent evaluation of a well-established interdisciplinary training program; and recommendations for the training of future biostatisticians. The purpose of this article is not merely to reiterate the call for interdisciplinary training, but to demand a more systematic and rigorous approach to evaluating the training modes currently in place to ensure that our efforts to produce interdisciplinary scientists are successful.

2. KEY DEFINITIONS

Today’s biomedical scientists are surrounded by new concepts and catch-phrases that describe current approaches to research questions. These terms include multi-disciplinary, inter-disciplinary, and even trans-disciplinary science. What do these concepts mean, and how can biostatisticians best become prepared to play a role in research teams of the future? Perhaps the most appropriate place to start this discussion is with some common definitions; then we can move toward the rationale behind these new approaches, how they are distinct from more traditional approaches, and how biostatisticians must be trained in order to advance and support new scientific approaches across a wide range of fields in health research.

Multidisciplinary, interdisciplinary, and transdisciplinary research approaches are related but distinct concepts. Rosenfield (1992) provided perhaps the clearest definitions:

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Multidisciplinary: Researchers work in parallel from their disciplinary-specific bases to address a common problem.

Interdisciplinary: Researchers work jointly from their disciplinary-specific bases to address a common problem.

Transdisciplinary: Researchers work jointly using a shared conceptual framework that draws together concepts, theories, and methods from the parent disciplines.

Figure 1 provides a visual depiction of these three approaches. The term “multidisciplinary research” applies to almost any kind of research initiative that involves the work of scientists from more than one discipline. It says little, however, about the way in which these scientists work together. One envisions individuals working in separate offices, joining their work together only as a final step toward completion. In contrast, interdisciplinary research involves joint work from the outset, and more integrative approaches. Like multidisciplinary research, interdisciplinary research involves scientists from more than one discipline. However, additional distinguishing characteristics of interdisciplinary research might include the collaborative development of specific aims and sharing of disciplinary-specific approaches, as well as the publication of resulting research findings in journals from a variety of disciplines, expanding the reach of their work. Transdisciplinary research represents yet another level, with joint work resulting in the development of new methods and approaches previously unused (or used very rarely) in any of the “parent” disciplines; and might even be considered as one step prior to the birth of a new, integrated discipline, combining the knowledge and skills of its predecessors.

In the sections that follow, we describe the rationale behind interdisciplinary research collaboration, existing programs and guidelines, and recommendations to enhance interdisciplinary training. We conclude with some thoughts about the risks of complacency and the need for us to apply the same rigorous standards to training that we apply to other areas of research.

3. THE RATIONALE FOR INTERDISCIPLINARY VERSUS “TRADITIONAL” SCIENCE

Why has interdisciplinary research come to the forefront of research activities? The answer rests with the types of questions being addressed. In general, more complex research problems require more complex approaches to achieve solutions. In the words of Elias Zerhouni, former director of the U.S. National Institutes of Health (NIH), “Solving the puzzle of complex diseases, from obesity to cancer, will require a holistic understanding of the interplay between factors such as genetics, diet, infectious agents, environment, behavior, and social structures” (Zerhouni 2003, p. 64). Consequently, the most successful “research teams of the future” (Zerhouni 2003, p. 64) will likely involve unexpected combinations of experts, such as “biological scientists, engineers, mathematicians, physical scientists, computer scientists, and others” (Zerhouni 2003, p. 64). We must go beyond bringing more diverse scientists to the table, however; we must lead them to work together in new ways: “The scale and complexity of today’s biomedical research problems increasingly demand that scientists move beyond the confines of their own discipline and explore new organizational models for team science” (Zerhouni 2003, p. 64). Adding to this complexity for biostatistical scientists are the huge advances in computer technology and the availability of fast, inexpensive...
computing resources; these enhancements have made it possible for biostatisticians to tackle much more complicated problems that could not have been addressed just 10 or 20 years ago. For example, issues of combining data from multidisciplinary sources and developments in spatial statistics (Zhu, Carlin, and Gelfand 2003) present complex challenges requiring interdisciplinary approaches.

It is interesting to note that support for interdisciplinary approaches is not new; leading research and educational experts have been promoting interdisciplinarity for decades. For example, Karl Popper, one of the leading philosophers of science of the twentieth century, noted that “We are not students of some subject matter, but students of problems. And problems may cut right across the borders of any subject matter or discipline” (Popper 1963, p. 88). Along this same thinking, Rustum Roy, another senior scientist and interdisciplinary thinker, observed that “…the real problems of society do not come in discipline-shaped blocks” (Roy 1977, p. 29).

With this motivation, interdisciplinary research efforts are receiving a tremendous amount of attention in the scientific literature, in the mission statements and grant opportunities of funding agencies, and in academic centers nationwide. The first of these three trends is evidenced in the work of Braun and Schubert (2003, 2007), who looked at the number of published articles appearing in Science Citation Index and Social Science Citation Index that included the terms “interdisciplinary” or “multidisciplinary” in their titles. Their work shows a staggering increase in the number of publications appearing annually that focus on interdisciplinary and multidisciplinary research. In the past 10 to 15 years, according to their work, the annual total number of such citations has more than doubled—from about 200 in 1994 to more than 400 in 2006. With respect to interest on the part of funding agencies, we searched the grant opportunities listed on the web sites of the NIH (http://www.nih.gov/grants/guide/) and the National Science Foundation (NSF; http://www.nsf.gov/funding/index.jsp) on November 21, 2010. Of 811 requests for applications and program announcements posted on the NIH web site, 162 (20%) mention interdisciplinary approaches, 207 (25%) mention multidisciplinary research, and 76 mention both; this means that overall, 293 opportunities (36%) point to interdisciplinary or multidisciplinary research methods. Similarly, the NSF searching web site indicates that 253 out of 651 funding opportunities (39%) highlight interdisciplinary research, and 138 (21%) stress multidisciplinary research approaches. Combined, 302 posted grant opportunities (46%) emphasize interdisciplinary approaches, multidisciplinary approaches, or both. Finally, academic institutions are increasingly focused on fostering environments in which interdisciplinary research can flourish (Brainard 2002; Breslow 2007; Redden 2008). This attention is welcome, as academia has a reputation for being “unfriendly” to more interdisciplinary, less traditional scholarship (Rhoten 2004); and many have observed that university incentive and rewards systems must be re-evaluated and modified to address this ongoing challenge (Pfirman et al. 2005; Committee on Facilitating Interdisciplinary Research 2005). It is widely recognized, furthermore, that venturing beyond one’s academic “silo” can be fraught with difficulty, due to lack of credentials or a track record in the other discipline(s), lack of familiarity with other disciplines’ language and terminology, and discomfort moving outside of one’s usual journals and conferences to spur broader and more diverse discussion of a challenging research problem. It is these obstacles that effective training programs must confront and overcome.

4. BRIEF REVIEW OF EXISTING TRAINING PROGRAMS AND GUIDELINES

The emphasis on interdisciplinary collaboration suggests that those embarking on careers in biostatistics today should be ready to participate as members and leaders of interdisciplinary teams. Biostatistics is a transdisciplinary field itself, arising from the melding of the fields of statistical science and biological systems, with particular emphasis on medical, public health, and agricultural applications. Given the transdisciplinary history of the field, we might assume that its members are perhaps more open to and skilled at interdisciplinary collaboration, but it would be a mistake to take this for granted. Despite the inherent interdisciplinarity of biostatistical science, it is fair to say that its practitioners embrace interdisciplinarity to varying degrees. How can we ensure that biostatistics training programs yield scholars who are prepared to enter and lead interdisciplinary research efforts? For the sake of this discussion, we will focus on doctoral level training, though many of our observations would apply equally well to master’s level training.

To better understand how biostatistics departments are incorporating interdisciplinarity into their curricula, we undertook a review of doctoral training program requirements from ten of the top-rated schools of public health (U.S. News & World Report 2011). We searched for any requirements that would involve exposure to disciplines outside of biostatistics (e.g., coursework or a minor from another department, engagement with interdisciplinary research projects in the form of a rotation or longer-term experience, training in teamwork or leadership skills, etc.). We recognize that our evaluation of online resources may be incomplete, and that some departments undoubtedly have additional requirements that are not posted on the Internet; however, we think this summary is probably a reasonably accurate assessment of interdisciplinary requirements, and gives us a sense of the degree to which interdisciplinary and teamwork skills are emphasized within these highly regarded programs. The summary is presented in Table 1. The table indicates that almost all of the departments studied require coursework outside of biostatistics, but only two require a research rotation or project in another discipline.

A number of excellent articles (Tobi et al. 2001; Zelen 2003; DeMets et al. 2006; Brown and Kass 2009) have studied the issue of interdisciplinary training in biostatistics and statistics, and developed a number of recommendations. First and foremost, biostatisticians need strong disciplinary training in the theory and methods of biostatistics (Zelen 2003; DeMets et al. 2006). While this may sound contradictory at first blush, all must understand the critical importance of a solid discipline-based foundation to their studies. One cannot be a valued interdisciplinary team member without having disciplinary strength to contribute to the collaboration. This point is emphasized in
### Table 1. Review of degree requirement websites for the biostatistics departments at the 10 top-rated schools of public health according to U.S. News & World Report (2011).

<table>
<thead>
<tr>
<th>School</th>
<th>Website</th>
<th>Required interdisciplinary coursework</th>
<th>Other interdisciplinary requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johns Hopkins University</td>
<td><a href="http://www.biostat.jhsph.edu/">http://www.biostat.jhsph.edu/</a></td>
<td>Ph.D. students must have at least 18 credit units of formal coursework outside of biostatistics department and at least 9 of these credits must be taken in the school of public health.</td>
<td>Students are required to develop expertise in a scientific area outside biostatistics (a scientific “minor”) through course work, self-study, directed reading, or other means.</td>
</tr>
<tr>
<td>University of North Carolina–Chapel Hill</td>
<td><a href="http://www.sph.unc.edu/bios/degrees_170_6190.html">http://www.sph.unc.edu/bios/degrees_170_6190.html</a></td>
<td>Ph.D. students: no cognate courses required.</td>
<td>Requires a “supporting program” of 6 semester hours for the Ph.D., and 18 semester hours for the DrPH, in a field or fields of application. A “field of application” is loosely defined as a discipline whose members might reasonably be expected to seek statistical consultation on occasion.</td>
</tr>
<tr>
<td>Harvard University</td>
<td><a href="http://www.hsp.harvard.edu/biostats/publications/handbook/">http://www.hsp.harvard.edu/biostats/publications/handbook/</a></td>
<td>Ph.D. students to take 10 credits from a nonquantitative field outside of biostatistics.</td>
<td>–</td>
</tr>
<tr>
<td>University of Michigan–Ann Arbor</td>
<td><a href="http://www.sph.umich.edu/biostat/programs/phd.html">http://www.sph.umich.edu/biostat/programs/phd.html</a></td>
<td>Ph.D. students must complete at least 9 hours of cognate courses from other departments.</td>
<td>–</td>
</tr>
<tr>
<td>Columbia University</td>
<td><a href="http://www.mailman.columbia.edu/academic-departments/biostatistics/academics/doctoral-program/phd/course-requirements">http://www.mailman.columbia.edu/academic-departments/biostatistics/academics/doctoral-program/phd/course-requirements</a></td>
<td>Ph.D. students must take at least two courses at the graduate level in their selected cognate field.</td>
<td>–</td>
</tr>
<tr>
<td>Emory University</td>
<td><a href="http://www.sph.emory.edu/cms/departments_centers/bios/degree_programs/phd.html">http://www.sph.emory.edu/cms/departments_centers/bios/degree_programs/phd.html</a></td>
<td>No cognate courses are required for Ph.D. students.</td>
<td>–</td>
</tr>
<tr>
<td>University of Washington</td>
<td><a href="http://www.biostat.washington.edu/grad/phd">http://www.biostat.washington.edu/grad/phd</a></td>
<td>Ph.D. students are required to take 15 credits of electives.</td>
<td>Ph.D. students must complete a “biology project.”</td>
</tr>
<tr>
<td>University of California–Berkeley</td>
<td><a href="http://sph.berkeley.edu/students/degrees/areas/biostat3.php">http://sph.berkeley.edu/students/degrees/areas/biostat3.php</a></td>
<td>Ph.D. degree requires 4–6 semesters of course work in biostatistics, statistics, and at least one other subject area.</td>
<td>DrPH requires participation in a research residency or professional residency in a public health setting in which the student has the opportunity to advance knowledge and skills, identify data for dissertation research, conduct analyses, and participate in decision-making.</td>
</tr>
<tr>
<td>University of Minnesota–Twin Cities</td>
<td><a href="http://www.sph.umn.edu/programs/biostatsphd/curriculum.asp">http://www.sph.umn.edu/programs/biostatsphd/curriculum.asp</a></td>
<td>Ph.D. students need to take at least one elective course from outside of biostatistics to fulfill the 12-credit requirement for a supporting field or minor.</td>
<td>–</td>
</tr>
<tr>
<td>University of California–Los Angeles</td>
<td><a href="http://www.biostat.ucla.edu/prospective-students/Admissions">http://www.biostat.ucla.edu/prospective-students/Admissions</a></td>
<td>Ph.D. students must complete a “third” field besides areas in biostatistics and mathematical statistics.</td>
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1. Examples of cognate fields include the biology of AIDS or cancer; environmental health; epidemiology; psychiatric genetics; health policy and management; society and health; human development; molecular biology; genetics; or other nonquantitative fields.

2. Cognate courses should be primarily applied as opposed to mathematics/statistical in nature. For example, courses in areas such as mathematics, statistics, operational research, computer science, econometrics, and psychometrics would most likely NOT qualify. Courses from other departments in public health or areas such as genetics, biology, psychology, economics, and many other areas would likely qualify as cognate courses.

3. Examples of cognate fields of study include biomedical informatics, computational biology, environmental sciences, epidemiology, genomics, health policy research, human biology, physiology, and imaging. The cognate fields of study need to be completed outside of biostatistics or statistics.

4. Of all 15 credits, 9 credits need to be chosen in Elective List Two: Biology or Public Health Emphasis. The rest of 6 credits are chosen from the Methodologic Emphasis courses in biostatistics/statistics. The Biology Project is to demonstrate that the student can digest information about scientific methods, principles, and mechanisms. The project should focus on basic life science rather than epidemiology or public health issues. The student can then expect 4–6 weeks of reading and study under the direction of this Advisor; the product of this study is a report by the student synthesizing results of this research. The report is a one-hour oral presentation with question-and-answer, attended by the student’s advisor.

5. “Third” field includes courses such as AIDS, biology, epidemiology, infectious diseases, medicine, microbiology, pharmacology, physiology, psychology, zoology, or public health.
the NAS report, which states that “even researchers who direct interdisciplinary teams prefer members who are expert in at least one field rather than ‘masters of none’” (Committee on Facilitating Interdisciplinary Research 2005). This raises a second question pertaining to preparation for entering a doctoral program in biostatistics. To succeed in a program that emphasizes theory and methods skills, one must enter with a strong background in mathematics. On the other hand, interdisciplinarity might be enhanced by the inclusion of students from a wide variety of backgrounds. The question of what constitutes “sufficient” mathematical background, then, is highly salient.

Rather than replacing disciplinary skills, the authors cited above favor additional, broader training beyond statistical theory and methods in order to prepare biostatisticians for careers involving interdisciplinary collaboration. This might include additional coursework or a minor concentration focusing on biology, genetics, epidemiology, or bioinformatics. Earlier authors recommend more than coursework, viewing as essential some exposure to genuine practical experience, not as described in a textbook, but as a member or observer of a working interdisciplinary team, perhaps during a research rotation. Zelen (2003) described just such a real-world experience as necessary for students to be able to make the “intellectual jump from theory to practice.” This recommendation has been echoed by Brown and Kass (2009), who noted that “cross-disciplinary projects will have to play a major role” in attracting a broader range of students to statistics and in developing problem-solving skills. DeMets et al. (2006) called for renewed consideration of postdoctoral fellowships for new biostatisticians. The postdoctoral period could provide opportunities for participation on interdisciplinary research teams with basic, translational, and clinical scientists, which might foster a greater comfort with and openness to engaging in cross-disciplinary collaboration in the future. Another recommendation was to include a dissertation co-sponsor from a field other than biostatistics, to give the trainee actual experience in collaborating with a non-biostatistician to identify worthwhile research questions and to craft new strategies and approaches. Another approach would be to invite visiting faculty who are practitioners (e.g., from industry, government research units, or health departments) to participate in student training as advisors or thesis committee members. Finally, DeMets and colleagues (2006) advocated formal training in leadership, communication skills, and personal effectiveness in order to ensure that trainees have the skills to thrive as members and leaders of interdisciplinary research teams.

It is interesting to compare the competencies for interdisciplinary biostatistics training to the learning objectives described by Borrego and News wander (2010), distilled from a study of IGERT (Integrative Graduate Education and Research Traineeship) programs; IGERT is NSF’s “flagship” interdisciplinary training program. Their qualitative analysis of 129 successful IGERT applications revealed four categories of student learning outcomes that commonly appeared in program proposals:

- Grounding in multiple traditional disciplines
- Integration skills and broad perspective of the interdisciplinary domain
- Teamwork
- Interdisciplinary communication.

Thus, there is substantial overlap between the IGERT learning objectives and the competencies described immediately above for biostatistics students (disciplinary strength, exposure to team projects, leadership and communication skills).

Is the combination of strong disciplinary training, leadership and communication skill-building, and interdisciplinary research experience enough to generate a truly interdisciplinary scientist? Is it even reasonable to expect that individuals can become more interdisciplinary in their approaches with such training? These questions have been raised by various authors in the biomedical sciences, without a particular focus on biostatistics (Petersen et al. 2005; Gebbie et al. 2008; Hackett and Rhoten 2009); their insights, however, can be applied to biostatisticians as public health professionals. Petersen and colleagues (2005) presented a case study, looking at an innovative approach to delivering an integrated core public health curriculum at the University of Alabama at Birmingham (UAB). Gebbie et al. (2008) undertook an initiative to define the required competencies for interdisciplinary research collaboration. Perhaps most interesting, Hackett and Rhoten (2009) launched an ambitious and innovative project to evaluate collaborative research skills among students enrolled in an NSF program to promote interdisciplinary scholarship (described in detail in the next section).

In the UAB experiment (Petersen et al. 2005), public health professors worked together to replace the standard core public health curriculum (usually composed of a series of five or six separate core courses, with no linkages between them) with an innovative, integrated curriculum consisting of a single, 15-credit core course combining modules from biostatistics, environmental health, epidemiology, health administration, and social and behavioral science. Compared to the “traditional” curriculum, they achieved significant gains in a number of areas, the most important of which is that students reported a better understanding of the inter-relationships among the public health disciplines, enabling them to approach public health problems from a team-based perspective, and to connect methods from multiple disciplines to address complex problems.

Gebbie and colleagues (2008) developed a set of 17 competencies for interdisciplinary scientists, based on expert panel opinion gathered through a Delphi panel process. Recognizing that disciplinary strength is “foundational for interdisciplinary success,” the authors recommended a number of new competencies that we might endeavor to nurture in trainees. Examples include: “integrate concepts and methods from multiple disciplines in designing interdisciplinary research protocols,” “draft funding proposals for interdisciplinary research programs in partnership with scholars from other disciplines,” “read journals outside his or her discipline,” and “attend scholarly presentations by members of other disciplines.” To instill these principles among students, the authors suggested adding an interdisciplinary component to traditional seminar series for pre-doctoral students, structured interactions with interdisciplinary...
teams and role models, and distribution of newsletters summarizing important findings from other disciplines.

5. LESSONS LEARNED: EVALUATION OF AN INTERDISCIPLINARY TRAINING PROGRAM

In 2006, researchers conducted a pioneering study to evaluate the success of NSF’s IGERT program. The mission of IGERT is “to catalyze a cultural change in graduate education, for students, faculty and institutions, by establishing innovative new models for graduate education and training in a fertile environment for collaborative research that transcends traditional disciplinary boundaries” (http://www.igert.org/public/about/history-and-mission). IGERT encompasses a broad array of disciplines from science, technology, engineering, mathematics, and the social sciences; its themes include sustainability, neuroscience, bioinformatics, climate change, human and social dimensions of new knowledge and technology, water, and energy. IGERT has funded more than 260 grants to 100 universities, which in turn have supported nearly 5000 students (http://www.igert.org/public/about). IGERT’s overarching goal is to deliver personal and professional skills needed by future leaders in science and engineering, but are they succeeding?

In an evaluation of the IGERT program, Abt Associates determined that educational experiences for students in IGERT training programs differed from those of students in non-IGERT programs (Abt Associates 2006). However, Hackett and Rhoten (2009) posited that this difference pertained only to “the organization and delivery” of training; the study did not address whether differences existed in the way IGERT students would conduct science compared to their non-IGERT counterparts. But how can this sort of difference be assessed? To answer this question, the researchers devised the “Snowbird Charrette.” Forty-eight graduate students in environmental science from IGERT and traditional (disciplinary) programs across the nation were recruited to participate in a two-and-a-half day experiment in Snowbird, Utah. They were assigned to work with fellow students in eight groups of six students each, with groups defined by program type (IGERT versus non-IGERT) and duration in graduate studies (1–2 years versus 3 years or more), resulting in two of each type of group. Each group was given a research problem in environmental science and asked to develop a brief (5-page) proposal and 20-minute presentation in response. A panel of experts then evaluated their work across five domains:

(i) Disciplinary quality
(ii) Interdisciplinary quality
(iii) Scientific reasoning
(iv) Intellectual merit
(v) Broader impacts.

The results are given in Figure 2. Among junior graduate students (those in training for only 1–2 years), IGERT students outperformed non-IGERT students in all five categories. However, among senior students (those with 3 or more years of training), the scores for non-IGERT (disciplinary) students exceeded those for IGERT students—even on the domain of interdisciplinary quality.

These results were not at all what the researchers expected to see. What happened to the senior IGERT students? To be sure, the experimental design is limited in scope and generalizability; it comprised a small sample in artificial circumstances around a single domain. Despite its limitations, however, we can learn from these data. Observers of group interactions noted that the senior IGERT students focused heavily on process—on the “social tactics” of collaboration, and less on the integration and synthesis of ideas. This finding suggests that we ought to give careful consideration to methods used for inculcating interdisciplinary skills in graduate trainees. Perhaps short-term, intermittent exposure to interdisciplinary science is not adequate to instill the required competencies.

6. RECOMMENDATIONS

The findings and recommendations above for interdisciplinary training can be used to inform the development of ad-
ditional guidelines and recommendations for training biostatisticians. To begin, let us summarize the recommendations posed by Zelen (2003), DeMets et al. (2006), and Tobi et al. (2001). These authors strongly support biostatistics training that incorporates:

- Rigorous training in statistical theory and methods
- Basic knowledge of a biomedical specialty area (e.g., imaging modalities, genetics and genomics, clinical trials, health outcomes research, epidemiology, basic laboratory methods, neuroscience, or computational biology)
- Experience in a team science setting, either in a post-doctoral fellowship or in a short-term (2–3 month) research rotation in a specific clinic or lab
- Training in communication and leadership skills, as well as research ethics.

Based on further consideration of research in interdisciplinary competencies and the evaluation of the IGERT program, we would recommend the following additional or modified requirements:

- The standard curriculum might be modified to include an integrative course, similar to the UAB example, which is shared across departments and involves faculty from multiple disciplines. While this is certainly an ambitious undertaking and would require the participation and dedication of many faculty outside of biostatistics, we think it is a goal that many departments might promote and pursue, as it could serve the needs of students from multiple disciplines.
- Program leaders might develop a longer-term integrative practical experience for students from multiple departments, who must work together to draft a proposal in response to a proposed research problem, similar to the Snowbird Charrette, but extended over a period of months. This could take the place of a short-term collaborative experience or research rotation, in which the student observes a research team in action but never has to function fully as a member of the team.
- Students should be required to reflect on their interdisciplinary team experiences. Educational research shows that reflection is a critical step in mastering the methods of a specific discipline (Schön 1983; Boud, Keogh, and Walker 1985), and is becoming increasingly common in clinical practice education in both medicine and nursing (Hannigan 2001; Ballon and Skinner 2008; Toy et al. 2009). Rotation-like experiences are enhanced by incorporating required “reflection” activities that force students, in written and/or oral presentations, to evaluate their experiences and review the skills they have acquired, and to establish how these skills relate to their disciplinary knowledge.
- In addition to coursework, students should be encouraged to attend seminar series and journal clubs in other units or departments—and especially within interdisciplinary centers, where students can gain knowledge, ask questions, and network with scientists from different disciplines and at varying levels of seniority.
- Program leaders might ask students to take an “interdisciplinary science readiness survey,” which assesses and highlights the interdisciplinary competencies proposed by Gebbie et al. (2008). Students might complete the assessment tool early in their training, and again when they are close to program completion, in order to evaluate their knowledge and attitudes regarding interdisciplinary collaboration and better prepare them to serve as members and leaders of interdisciplinary teams.
- It is essential that we, as scientists, consider various strategies for evaluating the training programs that we deploy. Tracking graduates over time will be important to gauge their career achievements. In addition to the “usual” metrics used to measure success (e.g., grants, publications, promotions), we might adopt novel indicators of interdisciplinarity, such as the measures proposed by Porter et al. (2007) for characterizing the degree of interdisciplinarity of a given body of work. Because interdisciplinarity is difficult to define, it is even harder to measure; and no single metric will be suitable in all circumstances. But Porter and colleagues have proposed two new metrics that are based on an individual’s publication record. The measures utilize the “subject categories” found in the Thomson ISI (Institute for Scientific Information) Web of Knowledge citation website. The measures incorporate both the number of subject categories that an individual’s articles cite, as well as the number of subject categories represented by the publications that cite any of the individual’s publications, taking into account the inter-relationships among the subject categories. These measures can then be used to characterize the degree of integration and specialization of a scientist’s work. These measures are new and relatively untested in the field, so further study is warranted to ascertain their utility in various settings.

7. DISCUSSION

A number of articles have pointed to the need for interdisciplinary training among graduate students in biostatistics (and in biomedical sciences more generally), but almost none of them discusses the evaluation of those efforts. We contend that it is not enough to add a few extra courses or short-term exposure to another discipline to foster an interdisciplinary mindset and skills; Hackett and Rhoten (2009) warned against this “disciplinary plus” approach. Rather, a longer-term immersive experience with extradisciplinary colleagues at various levels of seniority may be more effective in engendering the broad perspective and listening ability required for interdisciplinary success. We have no proof of this, however, and need to give serious thought to strategies for rigorous assessment. Methods for assessing our success are not obvious. It is imperative that we apply the same scientific and evaluative skills to our efforts in education that we apply every day in our research endeavors; otherwise, we cannot know to what degree our attempts at interdisciplinary education succeed.

The Snowbird Charrette, like any other human subjects research study, is flawed, due to its limited scope and sample size.
But those limitations certainly do not take away from the enormous achievements of the IGERT program. The overwhelming majority of IGERT students report that they have gained a broader and more interdisciplinary education compared to students in traditional programs, and they feel confident when entering the job market. This feedback suggests that the groundwork is laid, which is why the Snowbird findings are so surprising. It may be that the Snowbird Charrette simply looked too early, and that true interdisciplinary competence will blossom fully over time as IGERT trainees develop into mature scientists.

Another issue warranting further discussion is that of partners in training. Obviously, if we want to train biostatisticians to work in interdisciplinary teams, there must be students outside of biostatistics who are willing and able to work with them. Otherwise, it is rather like practicing conversational skills by talking into a mirror. This suggests that these efforts cannot be undertaken by a single department acting alone, but by several departments working together. School-wide initiatives provide an excellent platform for cross-departmental training, like that at UAB in Alabama. For example, faculty at the Columbia University Mailman School of Public Health are in the midst of a significant overhaul of the Master of Public Health (MPH) curriculum. The new educational structure will provide an integrated core curriculum, like that at UAB, but will move beyond that with longer-term (6–18 months) course-based projects for students from multiple disciplines, focusing on integrating science and practice as well as fostering leadership and innovation.

It is arguable that biomedical research is undergoing a paradigmatic shift, with much greater recognition of the importance of interdisciplinary research collaboration. It can also be argued that these new approaches and strategies are essential to our success in solving the complex health challenges facing us today: the etiology and treatment of mental illness, the burgeoning obesity epidemic, and the stubborn problem of tobacco and other substance addictions. We in the field of biostatistics must be ready to play collaborative and leadership roles in interdisciplinary science, and to prepare our students to excel in team research initiatives. It is hoped that our own interdisciplinary history, with biostatistics arising as a hybrid of the statistical and biological sciences, will provide us with a good springboard for our growth as interdisciplinary research leaders.

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REFERENCES


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