J Canc Educ (2014) 29:680–688
DOI 10.1007/s13187-014-0627-9

Mentoring by Design: Integrating Medical Professional Competencies into Bioengineering and Medical Physics Graduate Training

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Published online: 2 March 2014

Abstract Many students in bioengineering and medical physics doctoral programs plan careers in translational research. However, while such students generally have strong quantitative abilities, they often lack experience with the culture, communication norms, and practice of bedside medicine. This may limit students' ability to function as members of multidisciplinary translational research teams. To improve students' preparation for careers in cancer translational research, we developed and implemented a mentoring program that is integrated with students' doctoral studies and aims to promote competencies in communication, biomedical ethics, teamwork, altruism, multiculturalism, and accountability. Throughout the program, patient-centered approaches and professional competencies are presented as foundational to optimal clinical care and integral to translational research. Mentoring is conducted by senior biomedical faculty and administrators and includes didactic teaching, online learning, laboratory mini-courses, clinical practicums, and multidisciplinary patient planning conferences (year 1); student development and facilitation of problem-based patient cases (year 2); and individualized mentoring based on research problems and progress toward degree completion (years 3-5). Each phase includes formative and summative evaluations. Nineteen students entered the program from 2009 through 2011. On periodic anonymous surveys, the most recent in September 2013, students indicated that the program substantially improved their knowledge of cancer biology, cancer medicine, and academic medicine; that the mentors were knowledgeable, good teachers, and dedicated to students; and that the program motivated them to become well-rounded scientists and scholars. We believe this program can be modified and disseminated to other graduate research and professional health care programs.

Keywords Translational medical research · Mentors · Professional · Education · Competency-based education · Educational models · Program evaluation · Translational research · Doctoral education · Curriculum development · Educational model · Oncology education · Cancer biology · Mentoring · Multimodal education

Introduction

Cancer is the second leading cause of death in the USA in adults and children and represents a major public health problem globally [1]. Although Americans currently have a 20 % lower risk of dying from cancer than they did in 1991, when cancer death rates peaked, significant progress is still needed to diagnose cancer earlier and improve treatment, thereby improving patient outcomes. Today, worldwide cancer research efforts are focused on elucidating the underlying causes of disease and identifying persons at increased risk for developing certain cancers. Technologic advances have improved diagnostic modalities and intervention strategies, and novel biological therapies and biomedical devices are continually being evaluated for their ability to improve long-term outcomes for patients. As a result of an explosion of new discoveries, innovative research, and groundbreaking technology that had driven basic science rapidly forward, the

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National Institutes of Health in 2002 charted a "roadmap" for medical research in the 21st century [2].

Better outcomes for cancer patients will come about through cancer research, a principal subset of "translational research", defined by the National Institutes of Health as the movement of discoveries in basic research to application at the clinical level (sometimes referred to as the movement of discoveries "from bench to bedside") [3]. Cancer research spans traditional scientific disciplines of biology, genetics, epidemiology, biostatistics, medical physics, and behavioral sciences, as well as the emerging fields of bioengineering, bioinformatics, nanomedicine, computation science, and proteomics. The number of individuals projected to enter these diverse fields is unlikely to be sufficient to meet the needs of an aging and increasingly diverse population. Serious shortages in the oncology workforce are predicted by 2020 [4, 5], and the World Health Organization [6], professional organizations [7, 8], and others [9] have stated that to ensure rapid advances in oncology in the coming decades, the cancer research workforce must be invigorated with specialists from emerging fields who are well prepared to (1) ask scientific questions influenced by the experience of those who care for patients, (2) communicate effectively and work collaboratively with multidisciplinary oncology clinical and research teams, and (3) advance discovery and technology to improve diagnosis and discover new treatments and cures in the field of cancer medicine [6–9].

Doctoral students seeking successful careers in translational research must be able to design and execute hypothesis-driven research that will improve health outcomes, function as members of collaborative multidisciplinary biomedical teams, and understand the culture and political landscape of the academic health science center in the context of a broader health care climate. Traditionally, doctoral education programs for aspiring biomedical engineers and biomedical scientists have been designed primarily to develop "hard skills" required for independent scientific investigation. Most programs include didactic core science, technology, engineering, and mathematics courses followed by discipline-specific coursework and courses on research methodology, instrumentation, and experimentation. For students in such programs interested in a career in translational research, the traditional doctoral programs would be improved by the addition of innovative training in the culture, communication norms, and practice of bedside medicine.

Here, we describe a unique multimodal mentoring model successfully employed to teach medical professional competencies to biomedical engineers and medical physicists in graduate programs at Rice University and The University of Texas MD Anderson Cancer Center/The University of Texas Health Science Center Graduate School of Biomedical Sciences. Our program is taught at MD Anderson, a world leader in patient care, translational cancer research, and education with a strong track record of training scientists and clinicians to become vital participants in multidisciplinary cancer research teams. The model taught in our mentoring program is foundationally patient-centered and focuses on specific "soft skill" competencies of communication, biomedical ethics, teamwork, altruism, multiculturalism, and accountability. Through mentoring, our program teaches students that these professional competencies are essential for optimal clinical care and integral to translational research.

The "Med Into Grad" Initiative

Students entering translational research doctoral programs cite the desire to do clinically relevant research as an important motivation. However, recent reports show that only 16 to 20 % of Ph.D. graduates of these programs advance to tenure-track academic positions [10–13]. Howard Hughes Medical Institute (HHMI) president Thomas R. Cech noted "how difficult it is for scientists to harness the explosion of new biomedical research information and translate it into medical practice" [14]. Hence, in 2005, HHMI leaders developed the "Med Into Grad" (MIG) initiative "to encourage graduate schools to integrate medical knowledge and understanding of clinical practice into their biomedical curricula" to increase the pool of scientists successfully undertaking translational research [14].

Our MIG Program

Overview

We conceived of our MIG program as a means of bridging the gap between laboratory research and patient care. Thus, our program is portrayed as a bridge facilitating the flow of information between laboratory bench and patient bedside (Fig. 1). The base of the bridge is composed of professional competencies taught in medicine, and towers above the bridge signify the traditional academic courses taught in doctoral research programs. The bridge deck is designed for two-way traffic, which represents the opportunity for the researcher at the bench and the caregiver at the bedside to meet unimpeded anywhere along the interface between laboratory and clinic to discuss research in the context of the needs of patients. In this model, multidisciplinary conversations about patients' goals and expectations, clinical observations, diagnostic decision making, molecular profiling, "personalized" therapeutic targets, and advanced technologic interventions are as common as more narrowly focused discussions of clinical trial outcomes or experimental research results. Such conversations stimulate lively debate, facilitate collaborative problem solving, and inform rational design of future experimentation that will advance discovery and lead to improved outcomes for patients with cancer.

The MIG program principal investigator, director, and lead faculty are senior biomedical scientists (K.V.W., K.E.P.) and a

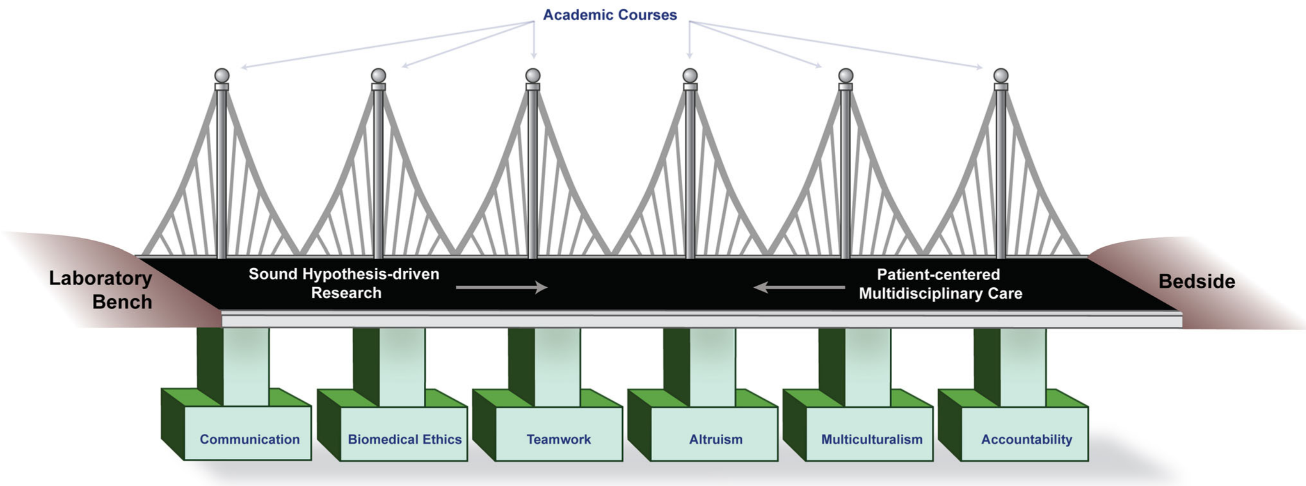

Fig. 1 Conceptual mentoring model: translational research bridge fortified by professional competencies

senior bioengineer (R.R.-K.) all with many years of experience in clinical and research teaching, educational administration, and mentoring.

Approach

Our MIG program, "Translational Cancer Diagnostics and Therapeutics for Bioengineers and Biophysicists," is one of the 23 funded MIG programs nationwide [15–18]. Our MIG program is a multidisciplinary fellowship that annually enrolls a small cohort of first-year doctoral students (six to eight students) from Rice University and MD Anderson. Designed to promote translational research at the interface of cancer biology, clinical medicine, and the quantitative sciences, our MIG program extends the traditional conceptual research framework by overlaying cancer biology and medicine themes onto the traditional bioengineering and medical physics programs using a rigorous multimodal developmental mentoring strategy with a focus on the patient undergoing clinical care for cancer (Fig. 2). Our MIG program promotes and seeks to instill clinical professional behavior through mentoring that encourages the development of professional competencies

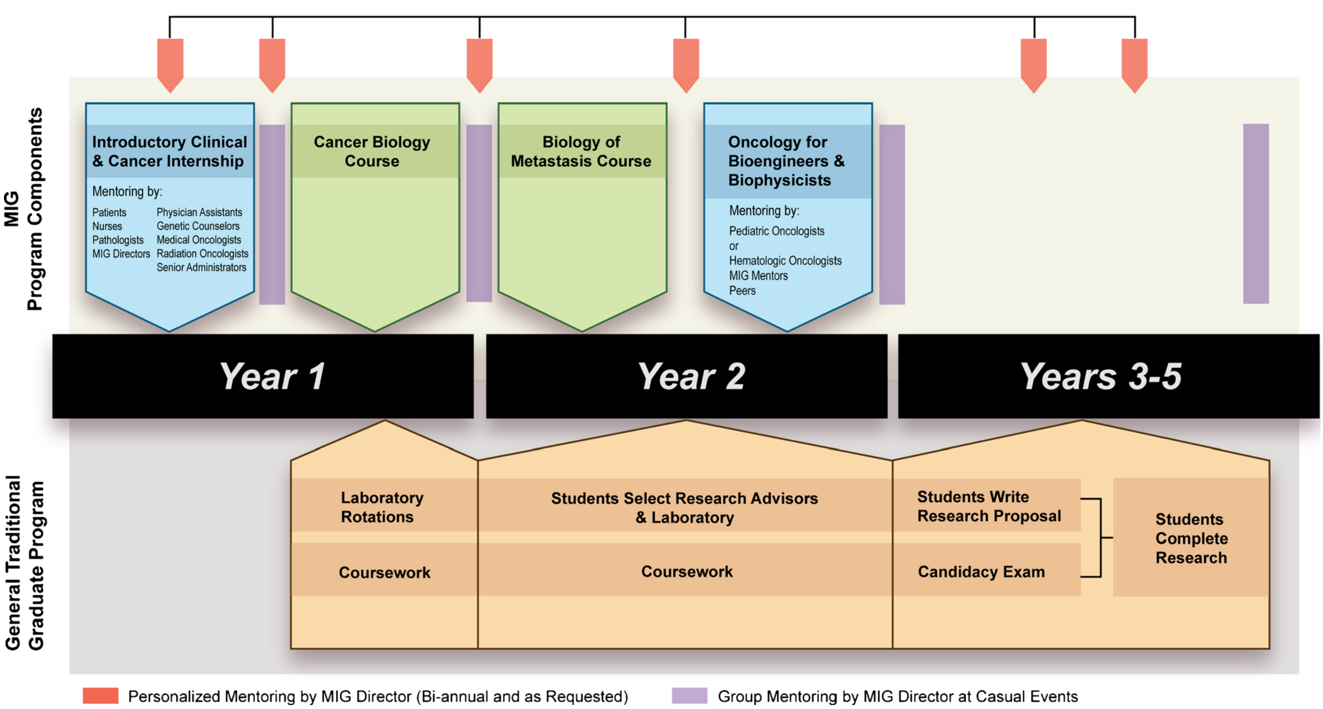

Fig. 2 Integration of the MIG program with a generalized graduate biomedical research program

taught in medicine (communication, biomedical ethics, teamwork, altruism, multiculturalism, and accountability).

Program Components

Candidates for our MIG program are individuals entering their graduate studies in bioengineering and medical physics who have little background in biological sciences, minimal clinical exposure, and negligible training in interpersonal communication skills. The professional competencies of the MIG program and the methods used to teach each competency are shown in Table 1.

The students begin the MIG program during the summer before year 1 of their formal graduate program with the intensive Introductory Clinical and Cancer Internship (Fig. 2). This 8-week "boot camp" introduces students to a multidisciplinary biomedical perspective. The summer internship is patient-centered and provides broad-based mentoring in the MIG program's professional competencies. Students take laboratory-based mini-courses in gross anatomy, histology, and pathology and traditional and online didactic mini-courses in physiology, cancer biology, and cancer medicine focusing on five cancer disease sites: breast, lung, colon and rectum, prostate, and head and neck. Students spend the last 3 weeks of the summer internship consolidating their knowledge during clinical rotations focusing on each of the five cancer sites. These rotations provide the opportunity for students to study diagnostic imaging, medical oncology, surgical oncology, and radiation oncology under the supervision of clinical oncology faculty.

After the summer internship, during years 1 and 2 of their graduate training, MIG students take additional courses in cancer biology, metastasis, mechanisms of therapeutics, and oncology. They attend and participate in numerous conferences, workshops, and lectures related to cancer biology and cancer medicine. The capstone course, Oncology for Bioengineers and Biophysicists, is a problem-based course in which each student works with a faculty expert to design, write, and formally present a hematologic or pediatric cancer case that includes all aspects of cancer care. The student's peers solve the case through problem-based learning. These cases pose ethical dilemmas, reflect cultural diversity, and require collaborative multidisciplinary problem solving.

Multiple learning formats are used in our MIG program, including didactic lectures, online learning, laboratory work (cadaver-based anatomical dissection and pathologic microscopy), discussions with experts, group presentations, individual presentations, workshops, facilitation of problem-based patient cases, individualized faculty mentoring, multidisciplinary patient planning conferences, clinical shadowing, site visits, and videos. Students evaluate each of the courses upon completion through anonymous online surveys. Students receive objective feedback in the form of test scores (on tests of anatomy and cancer biology) and receive subjective feedback from the program director regarding their mastery of professional competencies. Formative assessments are conducted at the conclusion of each semester, and summative assessments are conducted annually. Assessment results are delivered during a one-on-one mentoring meeting with the director of the MIG program. Students also receive written evaluations of their strengths along with suggestions for areas for improvement. Areas for improvement are reevaluated during the next assessment. Students perform SWOT analyses (Strengths, Weaknesses, Opportunities, Threats; Stanford Research Institute) for each course, and these analyses are used by the director, instructors, co-principal investigators, and advisory committee to continually improve the courses.

MIG Mentors

Students in our MIG program interact with 110 mentors in addition to the faculty who teach and serve as advisors in students' traditional graduate programs. Our MIG program provides training that is synergistic with that provided by the student's research advisor.

Literature on graduate mentorship has focused primarily on the function of the research advisor, who is undeniably one of the most influential guides for the graduate student as he or she develops into an independent scholar [19–21]. As chair of the student's dissertation committee, the research advisor directs the student's research training through scientific or engineering field selection, assists in coursework selection, and guides the student's training in hypothesis generation, methodology, and understanding of experimental pathways. The research advisor also models data presentation skills and advises the student in preparation of publications. Ideally, the research advisor also performs many other more informal mentoring roles for the student that set the stage for career success [22–25]. Noy and Ray [26] categorize graduate research advisors into six mentoring types: affective (therapists, perceived as caring for students' overall well-being), instrumental (serves as classic professor and professional mentor with the student as an apprentice), intellectual (provides feedback, assesses progress, directs research training), available (provides open-door availability to help with research and discuss progress), respectful (fosters interpersonal relationships that respect students' ideas, theoretical and substantive perspectives, and opinions), and exploitive (uses students as a source of labor, makes excessive time demands, treats students as indentured servants). With the exception of exploitive mentoring, each type of mentoring provides different dimensions of potential value to graduate students.

Our MIG program focuses on broadening the corps of mentors beyond the academic advisor and dissertation committee members, thus expanding the types of mentors available for students. The additional mentors available for

Table 1 Professional competencies and methods for teaching them

Competency and key related principles	Method(s) for teaching competency
Communication: Teammates from different disciplines should be fluent in both the language of hypothesis-driven biomedical research and the language of clinical medicine. All teammates should understand and respect the hierarchical nature of the clinical environment. Team members should become competent in communication between student and professional and communication between care provider and patient, including breaking bad news, and should be aware of potential communication barriers and sources of interpersonal conflict. Additionally, bioscientists and bioengineers should learn how to navigate and communicate with the governing bodies that influence, fund, and regulate biomedical research and academia	Summer internship, multiple health care mentors, patients and patient-advocate mentors, clinical internship, problem-based cases
Biomedical Ethics: A multidisciplinary team benefits when all of its members understand both the challenges inherent in clinical ethics as practiced at the bedside and the obligations of responsible conduct of research. Ethics consultations with cancer patients reflect the complexities inherent in clinical management. Appropriately honoring patients' confidentiality and wishes within the context of overall goals of care is crucial. Thoughtful consideration of the role of palliative care experts and the need for symptom control, end-of-life care and medical directives, and the patient's bill of rights are paramount in designing optimal management strategies for patients with cancer.	Summer internship, multiple mentors, student-selected topics in ethics (each student becomes an expert on a topic and formally presents it to the class), Oncology for Bioengineers and Biophysicists course, student-designed and student-facilitated pediatric and hematologic case studies
Teamwork: Researchers and clinical team members benefit from a reciprocal appreciation of each other's skills, for example, the scientist's ability to rapidly determine the patient's molecular status and the clinician's proficiency in obtaining data from a detailed medical history and comprehensive physical examination. Furthermore, understanding of patient preferences, clinical responses to therapy, and adverse short- and long-term effects of treatment is required to improve preclinical and clinical research design. To become effective problem solvers in a reengineered clinical research enterprise, new biomedical scientists and biomedical engineers should become effective citizen scientists and form a robust relationship with regulatory agencies, sponsors of research, the public (including patients and advocates), and policy makers.	All coursework, multiple mentors, research, clinical observations, seminars, problem-based case study, multidisciplinary patient planning conferences
Altruism: Academic health care professionals not only work extremely long hours to do both patient care and research, but often are less well compensated than their counterparts in private practice. There are altruistic reasons to work at the interface of discovery and clinical care, and it is important to examine the difference in clinical practice between an environment in which the primary motivation is financial gain and an environment in which the primary motivation is the desire to eliminate cancer. Additionally, patients agree to enroll in clinical trials for complicated reasons. Patients with cancer want to take advantage of the best and newest treatments, even when the treatments are unproven, and clinical trials allow patients to have access to such treatments. But patients may also be motivated by altruism and selflessness when their disease burden most likely precludes any possibility of a cure.	Patient and clinical mentors, clinical observation, problem-based case studies, multidisciplinary patient planning conferences, patient and patient-advocate mentors, multiple health care mentors, coursework
Multiculturalism: Researchers must be sensitive to cultural differences and how they influence patients' and families' experiences of and	Annual Disparities in Health in America Workshop, which includes lectures, panel discussions, and workshops;

Table 1 (continued)

Competency and key related principles	Method(s) for teaching competency
reactions to cancer and cancer care. Researchers must also appreciate and understand the challenges of "health disparities"—differences in the incidence, prevalence, mortality, and disease burden of cancer between different patient subgroups. Disparity is not solely an issue of access to medical care, but is a complex issue involving genetic, social, and societal factors that translational researchers should consider when designing their research.	personal mentoring by the conference chair; lectures on inclusion of all populations in clinical trials
Additional Professional Competencies: Researchers should understand the culture of the clinic (hierarchical, institutional), the roles and responsibilities of students in cancer clinics, clinical etiquette, patient advocacy, and patient safety. Researchers must also learn to use limited resources, provide uncompensated cancer care at times, and demonstrate accountability.	Summer internship, multiple clinical mentors, clinical internship, problem-based cases

students participating in our MIG program include senior administrators; basic, translational, and clinical faculty researchers; physicians; ethicists; physician assistants; nurses; genetic counselors; dosimetrists; speech pathologists; other members of multidisciplinary cancer care teams; and patients and patient advocates. These mentors serve as clinical preceptors, case study advisors, pathology preceptors, program leaders, co-principal investigators, doctoral advisors, research mentors, lecturers, and course and program directors.

In selecting mentors for our MIG program, we focused on choosing a team of mentors who had complementary skills and proven success in multidisciplinary collaborations. We also chose mentors to represent several generations of research and healthcare experts and patients. Finally, we chose mentors to reflect the cultural diversity of both the students in the MIG program and the translational cancer research workforce.

The first mentors the MIG students encounter are patients with cancer. The patients explain how their world has changed since their diagnosis of cancer. They discuss their diagnosis and treatment, detailing what their care providers did well and what they should have done differently. For example, during one summer internship, a young mother diagnosed with invasive breast cancer had recently undergone bilateral mastectomy and was currently undergoing chemotherapy. She "checked in" periodically with the students via telephone or web-based videoconferencing to describe her treatments, toxic effects of the treatments, physical and emotional responses to treatments, and difficulty in balancing her illness with her family's needs, and she answered questions from the students. She was highly influential in immersing the students into the world of cancer from a patient's perspective.

Most MIG mentors are health care professionals involved in direct cancer care. They are familiar with translational research and teach many formal academic mini-courses, serve as clinical preceptors, and model the professional competencies. MIG faculty mentors introduce students to the vocabulary, language, and culture of clinical medicine from their specific discipline's vantage point. MIG faculty mentors serve as intellectual mentors as they teach the didactic and laboratory courses that serve as a foundation for understanding cancer biology, cancer medicine, and eventually clinical rotations. Together with students, the mentors explore the molecular, microscopic, and clinical manifestations of cancer, as well as the ethical dimensions of the disease as they apply to patients and patients' families. MIG physician assistants, nurses, rehabilitation specialists, and genetic counselors often serve as affective mentors, teaching students what to expect and how to handle their emotions when they interact with patients and caregivers in the clinic and hospital. These mentors discuss the inner workings of the clinic, including its culture and hierarchy. They talk with the students about the patients' family histories, diagnoses, and goals and preferences in the context of comorbidities, as well as the psychosocial stress that patients experience following a cancer diagnosis. They also discuss their own mechanisms to maintain professionalism, reduce stress, and prevent burnout in their own careers.

The program director's role is to serve as a guide into the world of cancer illness and medicine for the students. The nature of the relationship between the program director and the student evolves significantly from the beginning of the program through graduation. It begins as a hierarchical relationship: the director has authority over the student, teaching and advising during group and individual presentations and evaluating the student's progress in mastering both the "hard skill" and "soft skill" competencies in the formal settings of the classroom, laboratory, and clinic. However, the relationship purposefully transitions over the course of the 5 or more years of the MIG program to a much more informal relationship in which power shifts from the director to the student [27]. The director employs reflective and coaching techniques as the student takes greater responsibility for bringing forward programmatic, multidisciplinary, and personal challenges for discussion and reporting successes. By graduation, the director and the student achieve a relationship that is more equally balanced and representative of colleagues who have learned together.

Additional roles of the MIG director include ensuring that special consideration is provided for students' race, gender, and international status; networking on behalf of students; writing letters of recommendation; advising on selection of advisors, postdoctoral fellowships, scholarships, funding sources, and jobs; assisting with preparation of proposals and oral candidacy examinations; assisting with poster production; and modeling good oral and written communication. The director assumes the role of each type of positive mentor (affective, instrumental, intellectual, available, and respectful, but not exploitive) at one time or another for each student during the program. Most importantly, the director serves as a "safe" mentor outside of the students' supervisory chain of command and research field who can act as a sounding board, promote reflective problem solving, and coach negotiating skills.

Preliminary Outcomes

Students

A total of 19 students entered the MIG program in 2009, 2010, and 2011. The format of the program as described above was used for the students who entered during those years. We selected students for the MIG program who had high grade point averages, strong scores on the quantitative part of the graduate school admission test, and previous research experience. The students graduated from the following universities: the University of Texas, Texas A&M University, Cornell University, the University of Hartford, Duke University, California Polytechnic University, the University of Notre Dame, Louisiana State University, Massachusetts Institute of Technology, the National University of Singapore, the University of Michigan, Iowa State University, Peking University, Boston University, Johns Hopkins University, Drexel University, and Clemson University. All students had previous research experience. Additional demographic data are presented in Fig. 3. At the time this paper was written, all students were still enrolled in their graduate programs except two, who have each graduated with a Ph.D. in bioengineering.

General Program Evaluation

Anonymous evaluation data were collected from students multiple times between August 2009 and June 2013 using SurveyMonkey software (SurveyMonkey.com). The surveys used both Likert scales and subjective narrative responses. Selected results are summarized below:

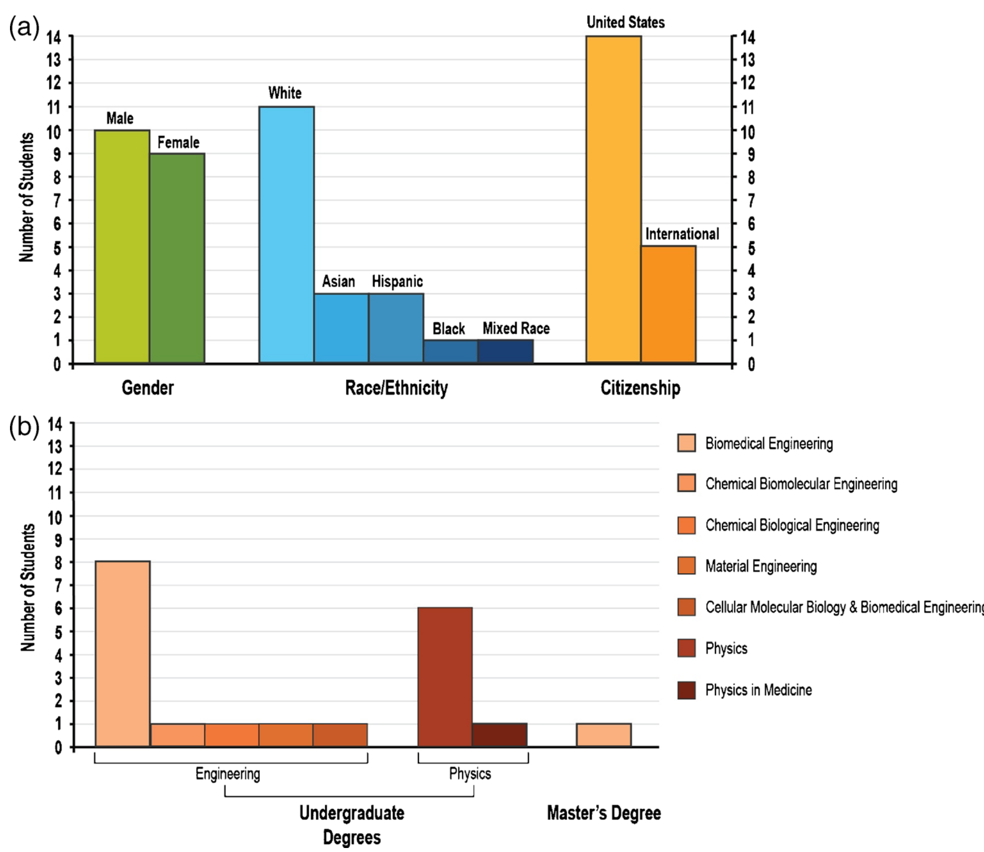

Fig. 3 Demographic data (**a**) and degrees (**b**) for students entering the MIG program in 2009, 2010, and 2011 (n=19)

All students ($n=19$) strongly agreed or agreed that the MIG program provided a valuable introduction to cancer diagnostics and therapeutics, filled gaps in their knowledge about cancer biology and medicine, expanded their medical vocabulary and enabled them to communicate more effectively in a clinical environment, and challenged and extended their capabilities.

All students cited very large, large, or moderate gains in the following: clarification of research interests, skill in interpreting research results, ability to identify and use research resources, understanding of how scientists work on real clinical problems, ability to analyze data and other information, learning ethical scientific conduct, skill in giving scientific presentations, ability to read and understand the scientific literature, skill in scientific writing, knowledge acquisition skills, awareness of concerns facing cancer care providers and patients, group interaction skills, understanding of how scientists think, understanding of professional behavior in a clinical setting, and becoming part of a learning community.

All students found the following extremely valuable or somewhat valuable: anatomy lab; pathology rotations; interaction with clinical experts; and rotations in diagnostic imaging, medical oncology, surgical oncology, radiation oncology, and genetic counseling.

All students strongly agreed or agreed that the program director and faculty demonstrated content expertise, displayed interest in students' educational advancement, were responsive to students' suggestions and were available and willing to mentor students and facilitate learning, and provided students with constructive criticism.

All students stated that they had improved understanding of research ethics; clinical ethics; clinical trials; health disparities; cultural sensitivity; informed consent; cancer screening, prevention, and staging; genetic risk assessment; cancer diagnosis; multidisciplinary cancer care; personalized medicine; and cancer biology.

When surveyed in September 2013, the students offered the following as some of the most valuable lessons learned from the MIG mentoring program: (1) always consider the potential impact of research on patients, (2) always seek a way for research to have meaningful clinical application, (3) work to obtain in-depth knowledge of cancer and its effects on patients throughout the trajectory of disease from diagnosis through survivorship or end of life instead of focusing narrowly on your own specific research domain, (4) study and respect the culture of the clinic and use appropriate clinical etiquette, and (5) focus not only on your research but also on your personal interests and seek work-life balance. The students were pleased with their mentors: students stated that they appreciated having highly individualized mentoring, that the program leaders knew the students and their goals well, that the mentors prioritized teaching and enjoyed teaching, and that students' were the mentors' priority and the mentors were interested in students' personal and professional growth beyond the program. The students valued personal evaluations because they offered insight and feedback into strengths and weaknesses. They appreciated being provided with a network of resources to help them progress in their careers. Students stated that the program motivated them to become well-rounded scientists and scholars and that the most important motivating factor was their mentors' belief that they would use what they learned to benefit others.

The other question asked was about the length of the Introductory Clinical and Cancer Internship. All students taking the course in 2009 recommended that the course be expanded from 7 to 8 weeks, which it was in subsequent years. The students in subsequent years responded that the 8-week course duration was optimal.

Conclusion

The MIG program at MD Anderson has successfully retooled traditional cancer research training, placing a new emphasis on collaborative multidisciplinary team problem solving in the context of actual cancer care culture and patient preferences. The program is fundamentally based on developmental mentoring that is patient-centered and grounded in professional practice. The authors believe that this model can be modified and disseminated to other graduate and professional health care programs.

Acknowledgments The authors thank the following individuals for their contributions to this paper: from Howard Hughes Medical Institute, Dr. Anh-Chi Le for sharing expertise on the Med Into Grad program; from The University of Wisconsin-Madison, Dr. Edward Jackson for sharing expertise on medical physics graduate teaching, research, and mentorship; and from The University of Texas MD Anderson Cancer Center, Dr. Greg Pratt for assistance with searching the mentoring literature, Dr. Fredika Robertson for sharing expertise on biomedical graduate research education, Maura Polansky for sharing expertise on the roles and responsibilities of students in cancer clinics, Erica Goodoff and Stephanie Deming for manuscript editing, Kathleen Wagner for graphical design, Alex Gomez and Steven Rosita for logistical and technical assistance, Martha Skender for sharing expertise on postdoctoral training, Dr. Oliver Bogler for sharing expertise on biomedical education, and Dr. John Hazle, Co-Principal Investigator of the Med Into Grad grant, for sharing expertise on graduate training in medical physics. We thank our Med Into Grad Fellows and their mentors. We thank Howard Hughes Medical Institute for their generous funding of the program.

Conflict of Interest The authors declare that they have no conflicts of interest.

References

1. Siegel R, Naishadham D, Jemal A (2013) Cancer statistics, 2013. CA Cancer J Clin 63(1):11–30
2. Zerhouni E (2003) The NIH roadmap. Science 302(5642):63–72

3. Woolf SH (2008) The meaning of translational research and why it matters. JAMA 299(2):211–213
4. Chang S, Cameron C (2012) Addressing the future burden of cancer and its impact on the oncology workforce: where is cancer prevention and control? J Cancer Educ 27(2):118–127
5. Erikson C, Salsberg E, Forte G, Bruinooge S, Goldstein M (2007) Future supply and demand for oncologists: challenges to assuring access to oncology services. J Oncol Pract 3(2):79–86
6. World Health Organization, Department of Human Resources for Health, Health Professions Network Nursing and Midwifery Office. 2010. Framework for action on interprofessional education and collaborative practice. http://www.who.int/hrh/resources/framework_action/en/. Accessed 13 June 2013
7. American Society of Clinical Oncology. 2011. Accelerating progress against cancer: ASCO's blueprint for transforming clinical and translational cancer research. http://www.asco.org/practice-research/ascos-research-blueprint. Accessed 12 May 2013
8. Association of Professors of Medicine Physician-Scientist Initiative (2004) Recommendations for revitalizing the nation's physician-scientist workforce. Association of Professors of Medicine, Washington, DC
9. Newhauser, Wayne D, Scheurer ME, Faupel-Badger JM, Jessica C, Jeffrey W, Woods KV (2012) The future workforce in cancer prevention: advancing discovery, research, and technology. J Cancer Educ 27(2):128–135
10. Powell, Kendall. 2012. The postdoc experience: high expectations grounded in reality. Available via Science Careers. http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2012_08_24/science.opms.r1200121. Accessed 22 June 2013
11. U.S. Department of Health and Human Services. 2012. Advisory committee to the NIH director Biomedical Research Workforce Working Group Data (Academic). In NIH Research Portfolio Online Reporting Tools. Science and Engineering Indicators 2012. http://report.nih.gov/investigators_and_trainees/ACD_BWF/Phd_Academic.aspx. Accessed 22 June 2013
12. U.S. Department of Health and Human Services. 2012. Advisory committee to the NIH Director Biomedical Research Workforce Working Group Data (Graduate). In NIH Research Portfolio Online Reporting Tools. Science and Engineering Indicators 2012. http://report.nih.gov/investigators_and_trainees/ACD_BWF/Phd_Graduate.aspx. Accessed 22 June 2013
13. National Science Board. 2012. Science and engineering indicators 2012. Arlington VA: National Science Foundation (NSB 12-01). http://www.nsf.gov/statistics/seind12/c5/c5s3.htm. Accessed 22 November 2013
14. Cech, Thomas R. 2006. HHMI awards $10 million to graduate programs that combine science and medicine. http://www.hhmi.org/news/20060215.html. Accessed 26 June 2013
15. Howard Hughes Medical Institute, HHMI News. 2009. The 2010 Med into Grad Grantees. http://www.hhmi.org/news/2010-med-grad-grantees. Accessed 15 January 2014
16. Smith CL, Jarrett M, Beth Bierer S (2013) Integrating clinical medicine into biomedical graduate education to promote translational research: strategies from two new PhD programs. Acad Med 88(1):137–143
17. McBride JM, Beth Bierer S (2012) Anatomists provide the foundation for learning pathophysiology. Anat Sci Educ 5(2):122–124
18. Hartmaier Ryan J, Shaffer DR (2009) Graduate students bring clinical know-how into their lab work through the HHMI Med into Grad program. Dis Model Mech 2(11-12):531–532
19. Charles HW, Karin S, Anne Marie Weber M, Begg MD, Fowler Jr VG, John H, Michael F (2011) Identifying and aligning expectations in a mentoring relationship. Clin Transl Sci 4(6):439–447
20. Paglis Laura L, Green SG, Bauer TN (2006) Does adviser mentoring add value? A longitudinal study of mentoring and doctoral student outcomes. Research in Higher Education 47(4):451–476
21. Price M (2012) Biomedical careers. Young researchers deserve more support, reviews say. Science 336(6088):1489–1490
22. Reckelhoff JF (2008) How to choose a mentor. Physiologist 51(4):152–154
23. Fleming M, Burnham EL, Charles Huskins W (2012) Mentoring translational science investigators. JAMA 308(19):1981–1982
24. Kjeldsen K (2006) A proficient mentor is a must when starting up with research. Exp Clin Cardiol 11(3):243–245
25. Lee A, Carina D, Phillip C (2007) Nature's guide for mentors. Nature 447(7146):791–797
26. Noy S, Ray R (2012) Graduate students' perceptions of their advisors: is there systematic disadvantage in mentorship? J Higher Educ 83(6):876–914
27. Rock Andrew D, Garavan TN (2006) Reconceptualizing developmental relationships. Human Resource Development Review 5(3):330–354