

Educational and Career Development Outcomes Among Undergraduate Summer Research Interns: A Pipeline for Pathology, Laboratory Medicine, and Biomedical Science

Lydia Pleotis Howell, MD¹, Sharon Wahl, MEd, MT (ASCP)¹, John Ryan¹ , Regina Gandour-Edwards, MD¹ and Ralph Green, MD, PhD¹

Abstract

Nurturing undergraduate students' interest in careers in science, technology, engineering, and medicine is important to developing the future health-care workforce. Summer research internships provide experiential learning that is important to sustaining students' interest in science, technology, engineering, and medicine careers and inspiring higher educational goals. The Edmondson Summer Research Internship is a mentored program for undergraduate students in University of California Davis Health's Department of Pathology and Laboratory Medicine. To evaluate intern satisfaction, perceptions on the program's influence on their career development, and higher educational outcomes, 102 former interns from a 15-year period were invited to participate in an online survey. Responses were received by 58 (57%) of 102 respondents. Not all respondents answered every question. Overall satisfaction was very high/high in 55 (95%) of 58. Ninety-three percent (54/58) strongly agreed/agreed that the internship was an important part of their career development. Almost all who applied to career/professional opportunities strongly agree/agreed that they perceived the internship to be advantageous (96%, 46/48). Forty-four percent (25/57) received additional education after completing their undergraduate degree, with 25% (14/57) receiving a doctoral degree. Few reported prior experience with a clinical laboratory (8/48, 17%), pathologist (10/48, 21%), or clinical laboratory scientist (12/48, 25%). Based on their internship experience, 55% (32/58) strongly agree/agreed that they positively considered pathology or laboratory medicine as a career choice. The Edmondson Summer Research Internship is seen as important to higher educational goals and career development, increases exposure to pathology and laboratory medicine, and demonstrates the value of hosting a mentored research program for undergraduates.

Keywords

career development, pipeline program, research internship, workforce development, educational outcomes, diversity, pathology and laboratory medicine

Received July 13, 2019. Received revised October 12, 2019. Accepted for publication October 19, 2019.

Introduction

The success of a community or nation strongly depends on its investment in the education and talent development among its young people. The Pew Institute analyzed US employment figures and found that employment in science, technology, engineering, and math (STEM) fields grew 79% from 9.7 million to 17.3 million Americans between 1990 and 2016,

¹ Department of Pathology and Laboratory Medicine, University of California Davis School of Medicine, Sacramento, CA, USA

Corresponding Author:

Lydia Pleotis Howell, Department of Pathology and Laboratory Medicine, University of California Davis Health System, 4400V Street, Sacramento, CA 95817, USA.

Email: lphowell@ucdavis.edu



Creative Commons Non Commercial No Derivs CC BY-NC-ND: This article is distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs 4.0 License (<http://www.creativecommons.org/licenses/by-nc-nd/4.0/>) which permits non-commercial use, reproduction and distribution of the work as published without adaptation or alteration, without further permission provided the original work is attributed as specified on the SAGE and Open Access pages (<https://us.sagepub.com/en-us/nam/open-access-at-sage>).

outpacing all job growth. This illustrates the importance of STEM education for workforce development.¹

Students' interests in STEM are often ignited through early life experiences in school, extracurricular activities, or through interactions with a relative or family member. Hands-on lab work, such as summer research internships, has also been shown to be an important though somewhat infrequent factor in sustaining students' interest in STEM careers and inspiring higher educational goals.^{2,3} A retrospective survey of students' participating in a summer internship demonstrated that 31% reported a change in their degree aspirations and almost 70% reported their preference to pursue a more advanced degree.²

Growing and sustaining students' interest in STEM careers is especially important to the future health-care workforce, including the physician workforce. The Association of American Medical Colleges (AAMC) predicts a physician shortage. For nonprimary care physicians, the AAMC projects a shortfall between 33 800 and 72 700 by 2030.⁴ This shortage is predicted to be especially acute in pathology and laboratory medicine since the average age of practicing pathologists is higher than any other specialty.⁵ Between 2005 and 2020, growth in practicing pathologists is projected to be only 3%, yet requirement projection for pathologists is estimated to conservatively be 23% but could be as high as 50%.⁶

Pathology is among the 10 specialties with the lowest rate of growth since 2000 among 35 medical specialties studied by the US Department of Health and Human Services.⁶ This likely reflects the drop in the percentage of US medical school graduates choosing the specialty, illustrated in the AAMC's annual graduation survey which reported only 1.3% of graduates entering pathology residencies in 2018, a small but steady decline from 1.5% in 2015.⁷ Pathologists are not the only group of laboratory professionals experiencing a workforce shortage. A substantial shortage of clinical laboratory scientists and other clinical laboratory professionals already exists.⁸ Many clinical laboratories have found PhDs who have completed clinical fellowships to be an important source of talent within clinical laboratories; as a result, there is interest in encouraging more young people interested in science to pursue this educational path toward laboratory-based careers.⁹

In this report, we share the value of sponsoring an undergraduate research internship in a department of pathology and laboratory medicine (DOPLM) by sharing interns' experience and educational outcomes from the most recent 15 years of the Edmondson Summer Research Internship,¹⁰ an 8-week mentored program for undergraduate college students which is based in the DOPLM at University of California Davis Health (UCDH; Sacramento, California).

The Edmondson Summer Research Internship was first founded at the University of Southern California (USC) in 1969 by Pathology Chair Emeritus Hugh Edmondson and brought to UCDH in the 1980s by Chair Emeritus Murray Gardner, MD, a former USC faculty member who became the pathology chair at UCDH. For over 30 years, this program has paired college and university undergraduates with faculty members and their laboratory teams for mentored research

experiences in the DOPLM. Interns receive a \$2000 stipend to support their participation in the program. Over the past 10 years, the program has expanded its scope to include (1) opportunities for clinical shadowing in different areas of pathology, laboratory medicine, and other medical specialties; and (2) a series of didactic lectures focusing on topics important to early career scientists. Interns are encouraged to participate in all departmental grand rounds and lectures as their laboratory research schedules allow. At the conclusion of the program, interns are expected to give a formal 20-minute oral platform presentation on their project to the other interns and faculty.

The goals of the Edmondson program are to provide talented and motivated undergraduate students with knowledge and skills in a research environment; instill love for science and foster lifelong learning; provide exposure to the field of pathology and laboratory medicine; promote new scientific research technologies that aid in patient diagnosis; and promote professionalism, honesty, integrity, compassion, leadership, and respect for academic excellence and community services.

Through the retrospective survey described in this study, we explore interns' perceptions on the Edmondson internship's influence on their career development and educational outcomes. We demonstrate how the Edmondson program enhances exposure to medical research, pathologists, and clinical laboratories and inspires the interns' interest in biomedical careers, including pathology, laboratory medicine, and clinical laboratory science.

Methods

The anonymous, web-based 18-question confidential electronic survey was designed with the focused purpose of gathering information on postinternship career development as well as interns' general perception of their experiences as part of a program review. The survey is intended to be a focused evaluation of the internship program and is not part of a prospective study. Survey questions appear in the Supplemental Appendix. The survey was designed by a subset of the authors (L.P.H., S.W., J.R.). The questions were modified from an unpublished survey developed and used to assess perceptions of experiential learning experiences among student volunteers at the UC Davis student-run clinics. The survey was not otherwise piloted or validated prior to use for the Edmondson interns. The survey questions were intentionally designed to employ best practices to avoid common survey pitfalls.¹¹ The best practices employed included questions that were neutrally worded and specific, with no negatively worded or "double-barrel" questions. To avoid careless responses or fatigue, the survey was relatively short in length, and response choices varied throughout the survey and did not frequently repeat, also consistent with published best practices.¹¹

The survey was implemented using SurveyMonkey. One hundred fifty-seven potential participants were identified through review of the files for the Edmondson Summer Internship Program from 2003 to 2017. The gender mix included 50% to 70% women annually, as well as participants from

Table 1. Demographics of Edmondson Summer Intern Survey Respondents.

	Total (% of Total)	Male (% of Total)	Female (% of Total)
Sex of respondents (n = 58)	58	20 (34)	38 (66)
Self-identifies as an underrepresented minority (n = 58)	11 (19)	4	8
Year of participation (n = 56)*			
2003-2007	9 (16)	2	7
2008-2012	11 (20)	3	8
2013-2017	36 (64)	16	20
Educational institution attended during Edmondson internship (n = 58)			
University of California campus	36 (57)	12	24
California State University campus	4 (7)	1	3
Public university, other state	3 (5)	2	1
Private university, California	2 (3)	0	2
Private university, other state	15 (26)	8	7
Community college	1 (2)	0	1

* Two of the total 58 respondents did not reply to this question.

diverse racial and ethnic groups. Active e-mail addresses were identified for 102 (65%) of 157 via departmental files and through social media, including LinkedIn and Facebook. Invitations to participate in the anonymous survey were sent by e-mail to the former Edmondson interns. Two subsequent e-mails were sent to this group with a reminder invitation to participate. This study included participants of many races and ethnicities, as well as some with disabilities. The survey results were collected and collated electronically. In accordance with federal regulations, institutional review board review was not required because the survey was designated as a program evaluation and does not constitute research as defined under 45 CFR 46.102(d).

Results

Fifty-seven percent (58/102) of former interns contacted responded to the survey. Demographics of the respondents appear in Table 1. The majority of the respondents were women, were enrolled in UC campuses as interns, and participated during the most recent time period.

Satisfaction was generally high for all components of the Edmondson internship (Figure 1). Overall satisfaction was reported as very high or high satisfaction (95%, 55/58) and no one reported being dissatisfied or very dissatisfied. Eighty-eight percent (51/58) of respondents were very satisfied or satisfied with their research experience and none very dissatisfied. Clinical shadowing experiences were introduced in the latter half of the Edmondson internship study period; thus, only 45 responses were received for this question. Ninety-six percent (43/45) were very satisfied or satisfied, 4% (2/45) were neutral, and none were dissatisfied or very dissatisfied.

Eighty-one percent (47/58) of respondents reported that they included the Edmondson internship on applications for professional opportunities (Figure 2) with research opportunities

most frequent (80%, 36/45), followed by graduate school (76%, 34/45), health-care job opportunities (58%, 26/45), volunteer opportunities (22%, 10/45), and other (4%, 2/45). Interviewers inquired about the Edmondson internship in two-thirds (67%, 29/43) of those who had interviews, and all but one were accepted to the opportunities that they applied for (98%, 41/43; Figure 2).

As illustrated in Figure 3, 93% (54/58) of respondents strongly agreed or agreed that the Edmondson internship was an important part of their career development, and the remaining 4 were neutral. Almost all of the respondents who reported applying to career or professional opportunities (96%, 46/48) strongly agree or agreed that they perceived the internship to be an advantageous component of their application. Only 2 were neutral or disagreed, and no one strongly disagreed. Based on their internship experience, 55% (32/58) strongly agree or agreed that they positively considered pathology or laboratory medicine as a career choice, 26% (15/58) were neutral, 14% (8/58) disagreed, and 5% (3/58) strongly disagreed.

Eighty-three percent (48/58) of respondents reported first-hand experience with at least one of the following prior to joining the program: research laboratories or scientists, physicians or surgeons, clinical laboratories or laboratory scientists, pathologists, and academic health centers. Most commonly reported was prior experience with research laboratories (60%, 35/58), research scientists (45%, 26/58), and physicians or surgeons (48%, 28/58; Figure 4). Least frequently reported was prior experience with a clinical laboratory (14%, 8/58), followed by experience with a pathologist (17%, 10/58), clinical laboratory scientist (21%, 12/58), or academic health center (21%, 12/58). A greater percentage of women respondents reported prior experiences than did men in almost every category (Figure 4).

Figure 5 illustrates current enrollment or highest degree obtained by Edmondson Summer interns to date. A bachelor's

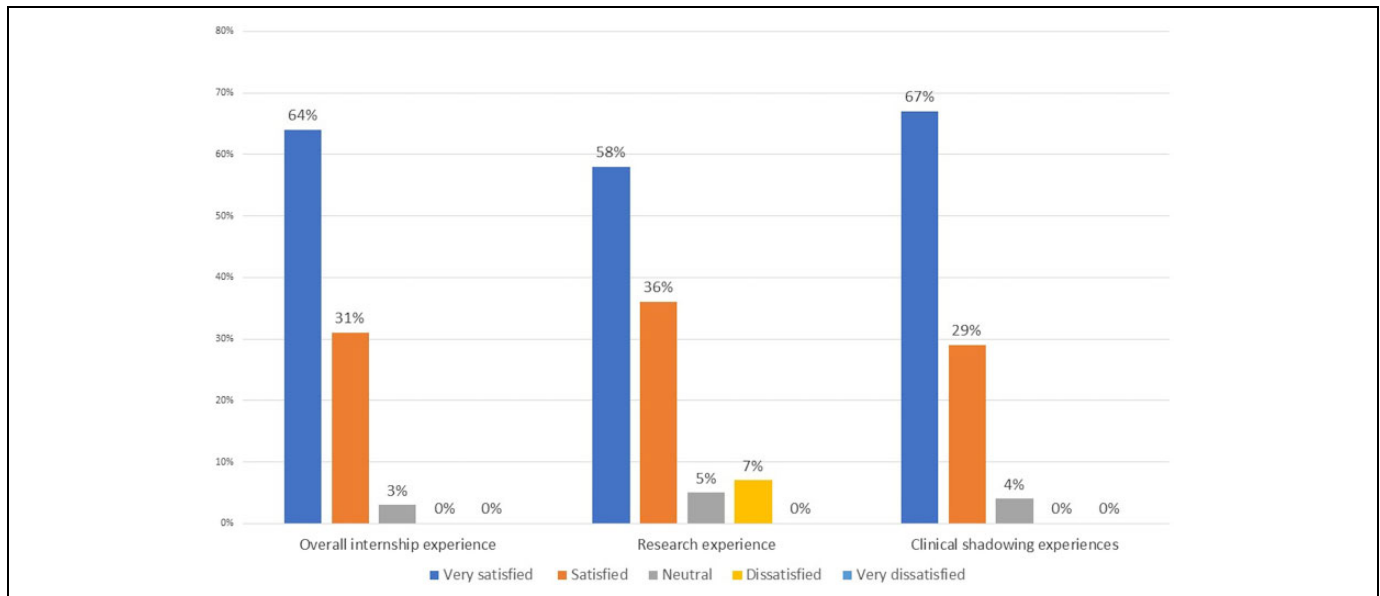


Figure 1. Satisfaction with Edmondson internship.

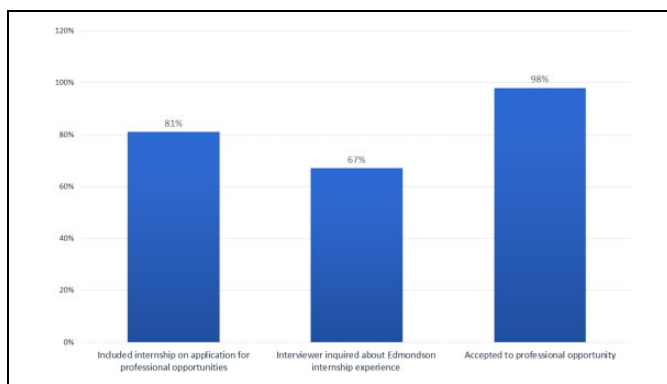


Figure 2. Relationship of Edmondson internship to professional opportunities.

degree was most common (40%, 23/57), followed by “some college but no degree” (19%, 11/57). Twenty-five percent (14/57) received a doctoral degree: a professional degree of some type (eg, MD, DDS, JD) was received by 14% (8/57), 9% (5/57) received a PhD, and a combination of professional and PhD was received by 2% (1/57). A master’s degree was received by 9% (5/57). Of the 58 respondents, 2 (4%) received a bachelor’s degree plus laboratory science training, and 1 (2%) each received a bachelor’s of science in nursing or an associate’s degree.

Almost half (47%, 27/58) of the respondents reported current enrollment in a degree granting program. Figure 5 includes the distribution of program enrollment. About one-third (37%, 10/27) are enrolled in some type of doctoral program, 22% (6/27) professional degree (eg, MD, DDS, JD) program, and an equal number of respondents are enrolled in either a doctoral program (eg, PhD, EdD, JD) or a combined PhD/professional degree program (7%, 2/27).

Written comments were received from 11 (19%) of 58 respondents and were very positive. Examples of comments and general themes identified among the comments are provided in Table 2. Respondents used many superlatives to describe the program, including “wonderful,” “valuable,” “amazing,” “great,” “a privilege,” and “best experience of my life.” Only 2 respondents recommended improvements. One indicated that she or he would have liked more clinical shadowing opportunities. The other noted feeling socially isolated as an out-of-state student and suggested more planned activities, especially on weekends, for the interns.

Discussion

Experiential learning in the form of internships are increasingly common and encouraged as part of the undergraduate educational experience. To facilitate this form of learning, many universities and colleges have created dedicated internship websites that provide advice and support on how students can find opportunities and make the most of their educational experiences. As illustrated on the UC Davis website,¹² internships are promoted as a valuable experience that allows students to apply knowledge gained in course work, develop new skills while refining others, explore potential career options, meet and work with professionals, establish a professional network, and experience new work environments that will make them more competitive in their future careers and in applications for jobs or to graduate or professional school. Internships have also been shown to be an effective method of learning since the internship mentor must apply many educational best practices, including active learning techniques, an emphasis on time on task, frequent faculty–student interactions, communication of high expectations, and prompt feedback.⁶ There are very few internship programs focusing on pathology and

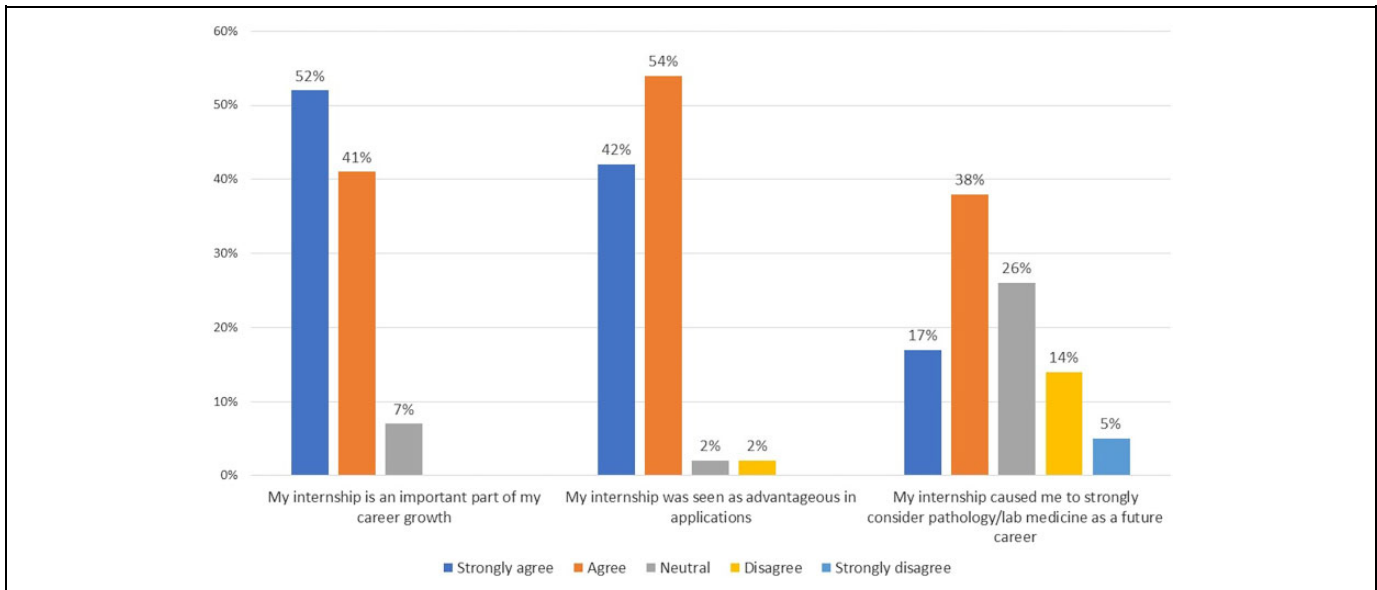


Figure 3. Perceptions on internship's influence on career development.

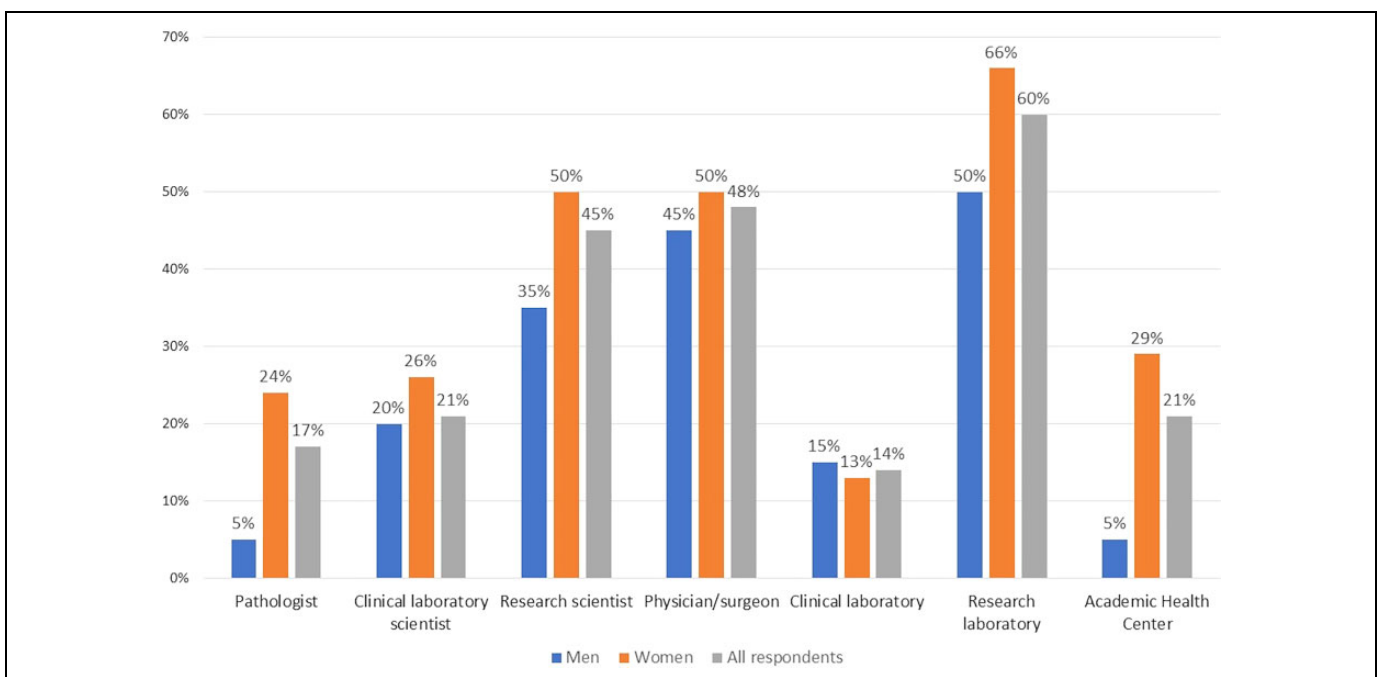


Figure 4. Firsthand experience with professionals or professional environments prior to Edmondson internship.

laboratory medicine. The website for the Association of Pathology Chairs provides a list of 7 internships; however, the UC Davis Health program appears to be the only internship based in an academic DOPLM.¹³

Each year, over 40 complete applications are received for the Edmondson program. Typically, 9 to 12 internship positions are offered annually based on available funding and mentors. The application process consists of review and scoring of each candidate's personal statement, academic transcript, and letters of recommendation by a committee of faculty and staff.

Based on scoring, finalists are identified for a web-based video interview using standardized interview questions. This interview is scored and points are aggregated with the previously assigned points and shared with the committee for final decision regarding acceptance.

To enhance efforts to recruit interns who are underrepresented in medicine and science, the Edmondson program began a partnership in 2017 with UC Davis Health's Prep Medico program, a pipeline program that is jointly sponsored by UC Davis School of Medicine and Kaiser Permanente, to increase

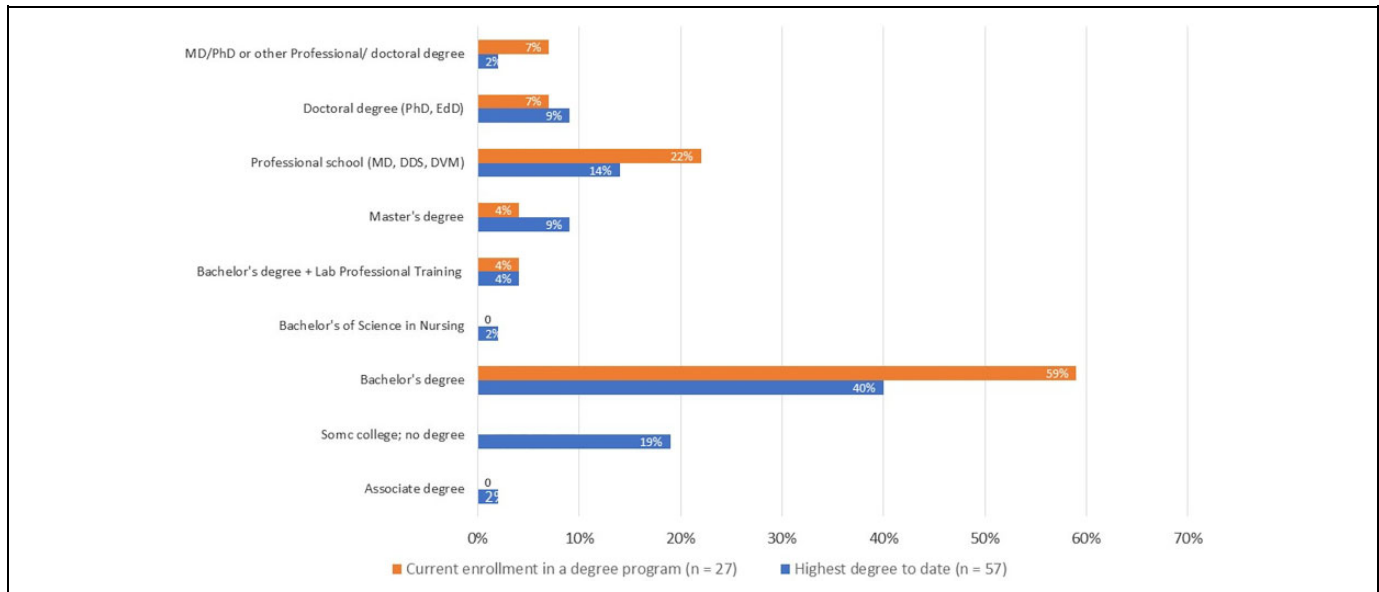


Figure 5. Current enrollment or highest degree obtained to date by Edmondson Summer interns.

Table 2. Written Comments From Survey Respondents.

Theme	Comments From Survey Respondents
Influence on career path	<p>“The Edmondson program was my very first exposure to doing research . . . Since Edmondson, I joined a research lab at my university and did more clinical research . . .”</p> <p>“My experience as an Edmondson intern really helped me develop a passion for clinical research and helped me become even more excited about going to medical school and becoming a doctor.”</p> <p>“Although I had been interested in a career in cancer research prior to the internship, this program cemented my interest in the field, and I remain engaged in the field now as a postdoctoral fellow. The research experience I gained in the program was valuable in informing my future research and as a great addition to my CV.”</p> <p>“This experience helped me determine once and for all whether or not I fit better in research/ academia or medical school. I have recommended this program to many other undergraduate students who are unsure of whether or not they want to do medicine or research. I think this program is an excellent tool in deciding which career path to follow.”</p>
Mentorship	<p>“It was a wonderful experience that taught me a lot about the field of research and this is exactly what I was looking for. The Edmondson program pairs students with leading scientists filled with wisdom and advice and this interaction is one overlooked aspect of research internships.”</p> <p>“I still talk with members of my PI's lab routinely and they've continued to play a large part in helping me get into medical school.”</p> <p>“I was able to publish and present my research. I remain in contact with my mentors to this day.”</p>
Exposure to field of pathology and laboratory medicine	<p>“I plan on using this experience to make me a stronger candidate when I apply to medical school. And knowing that being a pathologist is an option is also something I'm glad I got to know more about now.”</p> <p>“This experience acquainted me with laboratory medicine, and fueled my career ambition to become a clinical laboratory scientist.”</p> <p>“The experience helped to introduce and support serious interest in pursuing pathology as future career. I plan to definitely attend medical career in pathology research and encourage others to consider a career in pathology . . .”</p>

the number of Latino physicians and health-care professionals.¹⁴ In both 2017 and 2018, 4 students were accepted through the Prep Medico program as Edmondson interns.

The internship program consists of several components: (1) basic research skills and training (including compliance training) which are chiefly fulfilled online prior to joining the

program (see Table 3; additional training specific to individual labs may also be required, such as animal care); (2) didactic lectures in various domains (see Table 4); (3) tours and shadowing experiences (also included in Table 4); and (4) experiential learning in research laboratories under faculty mentorship.

Table 3. Required Online Training for Edmondson Interns.

Domain	Course Title	Delivery Source	
University policy	Privacy and Security Training	UC Learning Center*	
	UC Cyber Security Awareness Training	UC Learning Center	
	UC Sexual Violence and Sexual Harassment Prevention Training for Non-Supervisors	UC Learning Center	
	Workplace Violence Prevention in Healthcare	UC Learning Center	
	UC Compliance and Conflict of Interest for Researchers	UC Learning Center	
	Ergonomics in the Workplace	UC Learning Center	
	UC General Compliance Briefing: University of California Ethical Values and Conduct	UC Learning Center	
	Professionalism	Professionalism, Business Etiquette, and Personal Accountability	UC Learning Center
		Communicating with Professionalism and Etiquette	UC Learning Center
Addressing and Redistributing E-mail		UC Learning Center	
Laboratory	UC Laboratory Safety Fundamentals	UC Learning Center	
	Clinical Laboratory Biosafety	MTS† www.medtraining.org	
	Clinical Laboratory Chemical Safety	MTS www.medtraining.org	
	Clinical Laboratory Hazcom Standards	MTS www.medtraining.org	

* The UC Learning Center is the University of California's (UC) learning management system for training and development. Central authentication is required; accessible only by UC students and employees.

† Online training and competence assessment for the clinical laboratory, sponsored by the University of Washington's Department of Laboratory Medicine.

Mentors for the Edmondson internship are faculty members in the DOPLM who volunteer to participate in the program. Mentors include faculty in both the research-intensive and clinically intensive faculty tracks. No special training is required for participation as a mentor; however, the DOPLM is an active participant in UC Davis Health's Mentoring Academy¹⁵ and has been recognized twice with an award for outstanding mentorship by the Mentoring Academy. Many faculty members have participated in the Academy's faculty development workshops for mentors. During the time period studied, mentors were matched to mentees following a "speed-dating"-style process in which interns rotate among the mentors to learn about each other and the project offered. A preference list is then created by both mentors and mentees, which are then reviewed by the program coordinator to create matched pairs.

Table 4. Curriculum for Edmondson Interns.

Timeline	Activity
	Lectures:*
	"Introduction to Scientific Research. Fetal and Neonatal Treatment of Birth Defects with Stem Cells"
	"Pathology and Laboratory Medicine"
	Pathology Grand Rounds:
	Biomedical Engineering Capstone Project Presentations
	Lunch & Learn Presentation:
	"UC Davis All of Us Research Program"
Week 2	Lectures:*
	"Mentor/Mentee Responsibilities and Relationships"
	"Cultural Competency for Inclusive Learning"
	Shadowing/Tour Pathology Labs—Group 1
	Shadowing/Tour Pathology Labs—Group 2
	13th Annual Spotlight on Junior Investigators – A Cancer Research Mini-Symposium
Week 3	No lecture (July 4 Holiday)
Week 4	Pathology Grand Rounds:
	"Value-Based Reimbursement in Anatomic Pathology"
	"Clinical Chemistry"
	"Research Ethics"
	Clinical Shadowing, Group 2: Brain Cutting Conference'
	Coffee Talks:
	"Women in Medicine and Health Sciences"
Week 5	Lectures:*
	"Human Subjects Research (IRB)"*
	"Science Communication"
	Pathology Grand Rounds:
	"The U.S. Congress, The Administration and Precision Medicine"
	Discussion with the speaker—Edmondson interns
	Shadowing/Tours:
	California National Primate Research Center
	Veterinary Pathology Laboratory, School of Veterinary Medicine
	Student Intern Peer Reviews for the Poster Presentation
	Rehearsal Session:
	Maternal Child Health Careers/Research Initiatives for Student Enhancement – Undergraduate Summer Program (MCHC/RISE-UP) at UC Davis
Week 6	Lectures:*
	"Neuropathology of Alzheimer's Disease and Microglia Targeted Therapeutic Approach"
	"AI in Healthcare"
Week 7	Lectures:*
	"Role of Gut Microbiota on Human Pathology"
	"The Role of Personalized Medicine in the Care of Patients with Cancer"
	Presentation Practice—Group 1*
	Clinical Shadowing: Hematopathology sign-outs
Week 8	Lectures:*
	"Cancer: Beyond Genetics and Implications for Screening and Therapy"
	"Contemplating Your Future: Career and Opportunities in Medicine"
	Presentation Practice—Group 2*
	Pathology Grand Rounds:
	"Folic Acid and Neurodevelopmental Risk"
	Clinical Shadowing, Group 1: Surgical Pathology
	Clinical Shadowing, Group 2: Surgical Pathology
	Final Presentations—Group 1*
Week 9	Final Presentations—Group 2*

* Mandatory events designed for Edmondson interns only.

Important measures of success for an internship program are participants' satisfaction and their perception of the program's influence on their career paths and opportunities. Reported satisfaction with the Edmondson program was very high, consistent with the published experience from other research internships.^{2,16,17} Likewise, the interns' perception of the program's influence on their career paths was also high. This positive perception is further emphasized in the written comments that accompanied the survey and was likely reinforced by the fact that many were asked about their Edmondson internship during interviews for career opportunities and/or professional or graduate school.

Mentorship is a key attribute of the Edmondson program and emerged as a common theme in the written comments from our Edmondson survey respondents, illustrating their satisfaction and gratitude toward their mentors for their experiences and career opportunities. Mentorship has been shown to be a very influential component of successful internship experiences and career pathways in STEM. Studies have found that mentors influenced and even changed undergraduates' career paths, helped them prepare for graduate school, opened doors for them professionally, and facilitated important professional relationships.^{16,17} A high percentage of Edmondson interns attended graduate or professional school or pursued extra years of training for another health profession, such as nursing or clinical laboratory science. Although this is not a controlled study with a comparison group, others have shown that students with a mentor are more likely to maintain their interest in STEM and attend graduate or professional school.^{16,18}

Mentorship has been demonstrated to be especially important to women and minorities who may otherwise have a more difficult time developing a strong science identity without these important influencers and role models.^{19,20}

Interestingly, a higher percentage of women from the Edmondson program reported pursuing advanced education than men. This may reflect inherent gender differences in the participants: women who participate in programs such as ours may be an exceptionally motivated group since women often see themselves as having to "try harder" to succeed than men.²¹ There could also be a selection bias regarding those who choose to respond to surveys. Women were clearly overrepresented in the overall survey response group, and perhaps professionally successful women were even more likely to choose to respond. Alternatively, the predominance of women in graduate and professional school among Edmondson alumni may reflect the positive influence of mentorship and development of science identity in a group receptive for this support. Studies have shown that pipeline and enrichment programs lead to a greater rate of enrollment in graduate or professional school and a higher graduation rate among women as well as from ethnic groups underrepresented in STEM.^{18,22-25}

Internships often provide new experiences that help shape career choices. The provision of new experiences that inspire careers in science, including careers in pathology and laboratory medicine, is a secondary but important aspect to the Edmondson internship program. Substantial percentages of our

survey respondents reported previous experience with research labs, most likely reflecting their undergraduate experiences and the fact that our internship selection process favors students with prior laboratory experience. Prior interaction with a physician or surgeon was also commonly reported, mostly likely reflecting either their own health-care needs or those of family members. Interestingly, a much greater percentage of women than men reported previous experience with research laboratories or research scientists. Women are typically underrepresented in STEM and may again reflect a particularly motivated group of female participants. Relatively few respondents reported prior experience with a pathologist or a DOPLM. This is not an unexpected finding since this specialty does not have direct patient interaction and is often "behind the scenes" in relation to an individual's health-care experiences. The Edmondson internship therefore provided important exposure to the discipline of pathology and laboratory medicine as a new experience. The interns' experiences in pathology and clinical or research laboratory appear to have been impactful since more than half of the respondents strongly agreed or agreed that they would consider pathology and laboratory medicine/science as a career, and this was reiterated in the written comments in Table 2.

Limitations to this study include the absence of a control group, survey questions that had not been previously validated, moderate response rate of 57%, and the predominance of respondents who were women and who participated in the most recent time period.^{13-17,20} There were also relatively few respondents from underrepresented minority groups; however, a study by Lopatto did not find any evidence that minority students had a different internship experience than other students and that there were no difference in rates of discouragement or leaving science, pattern of learning gains, or satisfaction.² Like all survey-based studies, our findings have inherent limitations due to the self-reported nature of the data and potential recall or memory bias based on respondent perceptions which may have changed over time, attribution bias in which individuals provide a causal explanation for events which may or may not be real, and bias due to variability in individual experiences. Although it may not be possible to mitigate all of these biases, several factors related to this program evaluation minimize recall bias: (1) the length of the recall period that included the past 15 years rather than the entire 35+ years history of the Edmondson program, (2) the fact that the majority of the respondents were from the most recent 5-year period (2013-2017), and (3) the relatively young age of the respondents since recall and memory is known to decline with age.²⁶ Positive bias (ie, desire to please the questioner or provide socially desirable answers) is also possible, though the online format and the anonymous and confidential nature of the survey are methods that can minimize this bias.²⁷

Future directions for UC Davis' Edmondson Summer Research Internship include development of a rigorous evaluation process that meets newly established best practices and that provides outcomes that can meet recommendations from a recent report from the Office of Health and Human Services

on pipeline programs,²⁸ as well as meets recently published guidelines for ensuring excellence in quality improvement in education.²⁹ We are also exploring how to enhance the culture of diversity within the program as well as to provide appropriate social opportunities that can promote community among the interns and use the internship experience to build their network of peer professionals. We continue to grow the Edmondson program's relationship with the UC Davis Health's Prep Medico program to involve more students who are underrepresented in medicine and STEM. We are infusing diversity topics into the didactic curriculum to illustrate the importance of supporting diversity in research. Potential topics under consideration include challenges and best practices in recruiting research participants from diverse backgrounds and exposure to research on the social determinants of health. In 2019, we piloted a new web-based method to match interns and mentors prior to the program's start in order to better address institutional on-boarding requirements and to provide more time in the laboratory, and we plan to evaluate and monitor the effectiveness of this method for meeting interests of students and the needs of mentors.

In summary, this survey demonstrates that the Edmondson Summer Internship Program is a successful program that supports participants' interest in science, provides valuable exposure to the field of pathology and laboratory medicine/science, inspires interest in graduate or professional school, and creates new professional networks with mentors that extend beyond the internship program. Mentoring undergraduates exposes them to clinical laboratory careers as well as to graduate programs and promotes the educational and training programs within UC Davis' DOPLM. The program also supports our goal for educational outreach and growing our community relationships. The UC Davis experience demonstrates the value of hosting mentored research experiences for undergraduates in a DOPLM.

Acknowledgments

The authors thank UC Davis Medical Centers for providing financial support for this program throughout its existence. The authors also thank the many faculty from the DOPLM who have served as inspirational mentors to the Edmondson interns since the program's inception, as well as to their laboratory staff who provide essential support and supervision, and to faculty from many clinical departments who generously welcome the interns for shadowing experiences in the hospital and clinics. The authors also thank the current program coordinator Gabriela Lee, MBA, who provided curricular information. Special thanks are extended to those who nurtured the Edmondson program in the years prior to the period studied in this survey: Department Chair Emeritus Murray Gardner, MD, who founded the program at UC Davis Health; Chair Emeritus Robert Cardiff, MD, PhD; program directors Claramae Miller, PhD, and Jiunn Huang, MT (ASCP); and faculty Hanne Jensen, MD, and Anthony Cheung, PhD.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

John Ryan  <https://orcid.org/0000-0002-0607-4292>

Supplemental Material

Supplemental material for this article is available online.

References

1. Pew Research Center. Women and men in STEM often at odds over workplace equity. 2018. http://www.pewsocialtrends.org/wp-content/uploads/sites/3/2018/01/PS_2018.01.09_STEM_FINAL.pdf. Accessed September 6, 2019.
2. Van Meter-Adams A, Frankenfeld CL, Espina V, Liotta LA. Students who demonstrate strong talent and interest in STEM are initially attracted to STEM through extra-curricular experiences. *CBE Life Sci Educ*. 2014;13:687-769.
3. Lopatto D. Undergraduate research experiences support science career decisions and active learning. *CBE Life Sci Educ*. 2007;6:297-306.
4. Dall T, West T, Chakrabart R, Reynolds R, Iacobucci W. The complexities of physician supply and demand: projections from 2016-2030. Association of American Medical Colleges. 2018. https://www.researchgate.net/publication/331555846_2018_Update_The_Complexities_of_Physician_Supply_and_Demand_Projections_from_2016_to_2030_Final_Report_Association_of_American_Medical_Colleges. Accessed September 6, 2019.
5. Robboy S, Weintraub S, Horvath AE, et al. Pathologist workforce in the United States: I. Development of a predictive model to examine factors influencing supply. *Arch Pathol Lab Med*. 2013;137:1723-1732.
6. US Department of Health and Human Services, Health Services Resources and Service Administration, Bureau of Health Professions. The physician workforce: projections and research into current forces affecting supply and demand. 2008. <https://bhw.hrsa.gov/sites/default/files/bhw/nchwa/projections/physiciansupplyissues.pdf>. Accessed September 6, 2019.
7. Association of American Medical Colleges. Medical school graduation questionnaire: 2018 all schools summary report. 2018. <https://www.aamc.org/download/490454/data/2018gqallschoolssummaryreport.pdf>. Accessed September 6, 2019.
8. Caldwell B. ASCP laboratory workforce report. American Society of Clinical Pathology. 2018. https://ftp.cdc.gov/pub/CLIAAC_meeting_presentations/pdf/Addenda/cliac0418/10_Caldwell_Workforce.pdf. Accessed September 6, 2019.
9. Lorenz RD, Karcher DS, Gatreux MD, Limson M, Zander D. The pathology workforce and clinical licensure: the role of the PhD clinical laboratorian in the United States. *Acad Pathol*. 2018; 5. doi:10.1177/2374289518775948.
10. Hugh Edmondson Research Internship. https://health.ucdavis.edu/pathology/education/edmondson_research_fellowship/. Accessed September 6, 2019.

11. Sullivan GM, Artino AR. How to create a bad survey instrument. *JGME*. 2017;9:411-415.
12. UC Davis Internship and Career Center. <https://icc.ucdavis.edu/find/internships>. Accessed September 6, 2019.
13. Association of Pathology Chairs. Opportunities in pathology for high school, college, post-baccalaureate and medical students. https://www.apcprods.org/assets/docs/students/APC_PathologyOpportunities_Pre-Medical%20Students%20%282019%29.pdf. Accessed September 6, 2019.
14. UC Davis Health Prep Medico. https://www.ucdmc.ucdavis.edu/diversity-inclusion/prep_medico/Prep_Medico.html. Accessed September 6, 2019.
15. UC Davis Health Mentoring Academy. <https://health.ucdavis.edu/facultydev/mentoring-academy/>. Accessed September 6, 2019.
16. Chickering AW, Gamson ZF. Seven principles for good practice in higher education. *AAHE Bulletin*. 1987;3-7.
17. McSweeney JC, Hudson TJ, Prince L, et al. Impact of the INBRE summer student mentored research program on undergraduate students in Arkansas. *Adv Physiol Educ*. 2018;42:123-129.
18. Kolber BJ, Jancic JM, Pollock JA, Tidgewell KJ. Summer research undergraduate research: a new pipeline for pain clinical practice and research. *BMC Med Educ*. 2016;16:135. doi:10.1186/s12909-016-0648-7.
19. Alfred LJ, Atkins C, Lopez M, Chavez T, Avila V, Paolini P. A science pipeline pathway for training underrepresented students in the biomedical sciences. *J Women Minor Sci Eng*. 2005;11:45-60.
20. Merolla DM, Serpe RT. STEM enrichment programs and graduate school matriculation: the role of science identity salience. *Soc Psychol Educ*. 2013;16:575-597.
21. Salto LM, Riggs ML, De Leon DD, Casiano C, De Leon M. Underrepresented minority high school and college students report STEM-pipeline sustaining gains after participating in the Loma Linda University Summer Health Disparities Research Program. *PLoS One*. 2014;9:e108497.
22. Gorman EH, Kmec JA. We (have to) try harder: gender and required work effort in Britain and the United State. *Gender Soc*. 2007;21:828-856.
23. Cregler LL. Enrichment programs to create a pipeline to biomedical science careers. *J Assoc Acad Minor Phys*. 1993;4:127-131.
24. Coronado GD, Shuster M, Ulrich A, Anderson J, Loest H. Strategies for diversifying the pool of graduate students in biomedical sciences. *J Cancer Educ*. 2012;27:436-442.
25. Salto LM, Riggs ML, Leon DDD, Casiano C, De Leon M. Underrepresented minority high school and college students report STEM-pipeline sustaining gains after participating in the Loma Linda University Summer Health Disparities Research Program. *PLoS One*. 2014;9:e108497.
26. Villarejo M, Barlow AEL, Kogan D, Veazey BD, Sweeney JK. Encouraging minority undergraduates to choose science careers: career paths survey results. *CBE Life Sci Educ*. 2008;7:394-409.
27. US Department of Health and Human Services, Health Services Resources and Service Administration, Bureau of Health Professions, Office of Public Health and Science, Office of Minority Health. Pipeline programs to improve racial and ethnic diversity in the health professions: an inventory of Federal programs, assessment of evaluation approaches, and a critical review of the research literature. <http://www.aapcho.org/wp/wp-content/uploads/2012/11/PipelineToImproveDiversityInHealthProfessions.pdf>. Accessed September 6, 2019.
28. Althulbaiti A. Information bias in health research: definition, pitfalls, and adjustment methods. *J Multidiscip Healthc*. 2016;9:211-217. doi:10.2147/JMDH.S104807.
29. Ogrinc G, Armstrong GE, Dolansky MA, Singh MK, Davies L. SQUIRE-EDU (Standards for Quality Improvement Reporting Excellence in Education): publication guidelines for educational quality improvement. *Acad Med*. 2019;94:1461-1470.