

Chicago EYES on Cancer: Fostering Diversity in Biomedicine through Cancer Research Training for Students and Teachers

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ABSTRACT: The National Cancer Institute’s Youth Enjoy Science Research Education Program (YES) supports cancer-based research experiences, curriculum development and outreach activities to foster diversity in the biomedical workforce. The University of Chicago Medicine Comprehensive Cancer Center was among the first recipients of the YES award in 2017, launching the Chicago EYES (Educators and Youth Enjoy Science) on Cancer program for high school and college students. The EYES team also introduced immersive research experiences and mentored curriculum development for high school science teachers, a potentially powerful means to extend science enrichment and career exposure to schools across Chicago. Ongoing evaluation of the EYES program suggests positive outcomes in terms of trainees’ research skill development and their knowledge about, and positive attitudes towards, careers in biomedicine. Teacher research fellows reported that the program inspired new insights about science learning and practice that not only strengthened their skills as science educators, but also improved their ability to relate to their pupils. These findings contribute to the broader effort to establish best practices among cancer research training programs, particularly those with a shared mission to empower youth from diverse backgrounds to contribute to a field deeply in need of their talents and perspectives.

INTRODUCTION

In 2016, as one of its latest initiatives to increase diversity in the biomedical research workforce, the National Cancer Institute (NCI) introduced the Youth Enjoy Science (YES) Research Education Program (R25) for individuals from diverse backgrounds in grade 6 through college, as well as for grade 6-12 teachers and undergraduate faculty serving underrepresented student populations (Lin, 2022; National Institutes of Health, 2016). The program supports educational activities focused on three core areas—research experiences, curriculum development, and outreach—to “inspire interest in biomedical sciences, elevate research as a career path, and strengthen practical research and career skills” (National Institutes of Health, 2021, np).

The University of Chicago Medicine Comprehensive Cancer Center (UCCCC) was among the first recipients of the YES grant, launching Chicago EYES (Educators and Youth Enjoy Science) on Cancer. The program replaced and expanded the UCCCC’s NCI-funded Continuing Umbrella of Research Experience (CURE) program, initiated in 2014, for high school and college students. Importantly, the broad scope of the YES grant allowed the UCCCC also to provide immersive cancer research training opportunities to high school science teachers, a potentially powerful means to build capacity and extend science enrichment and career exposure to a much larger group of students than can enroll in the EYES program directly.

There is strong rationale supporting research experiences for both students and teachers to promote greater interest, capacity, and persistence among young people regarding careers in science, including those from underrepresented backgrounds (Lin, 2022; National Academies of Sciences, Engineering, and Medicine, 2017). Together, reviews by Sadler and colleagues (Sadler et al., 2010; Sadler and McKinney, 2010) and Krim and colleagues (2019) summarize findings from nearly 60 years of literature on the impact of immersive research experiences for high school students, undergraduates, and K-12 educators. They report evidence of gains across multiple domains, including research skills, understanding of scientific content knowledge, confidence for doing science, and among students, science-related career aspirations and achievements. Outcomes appear to be strongest for programs that offered more extended research opportunities (i.e., those lasting longer than a summer or semester); programs that complemented research experience with explicit instruction targeting desired outcomes; and programs that engaged trainees in epistemically demanding practices (e.g., data analysis) (Sadler et al., 2010; Sadler and McKinney, 2010). Persistent gaps in the literature highlight the need for ongoing research, specifically with regard to outcomes for participants from underrepresented populations, theoretical frameworks supporting program design and evaluation, and, for teacher programs, the processes through which research experiences impact classroom instruction and student learning (Krim et al., 2019).

In the present paper, we describe the context, theoretical framework, and core components of the Chicago EYES on Cancer program, which serves one of the largest and most diverse cities in the country. We also report preliminary findings with regard to program implementation, participant experience and participant outcomes. These insights contribute to the broader effort to establish best practices among YES

programs and cancer research training programs more generally, helping to empower youth from diverse backgrounds to contribute to a field deeply in need of their talents and perspectives.

Chicago EYES on Cancer. With close to three million residents, Chicago is the third-largest city in the nation. It has the dubious distinction of also being among the most segregated (University of California Berkeley, 2021), one factor driving persistent and devastating health disparities among local populations, including with regard to cancer incidence and mortality (Ansell, 2017; Jones et al., 2017; Rauscher et al., 2012; Sighoko et al., 2018). Over the last five years, Chicago EYES on Cancer has become an integral component of the UCCCC's strategy to address cancer health disparities. Specifically, it is the keystone in the center's initiatives to diversify the cancer research workforce by engaging youth from across Chicagoland in research training and career exploration.

Between Chicago's massive public school system and rich landscape of colleges and universities, EYES has access to a deep pool of high school and undergraduate students interested in careers in science and medicine. Program applications consistently top 200 per year for 12 slots, yielding an average acceptance rate of just 5.1%. The applicants themselves are ambitious; they describe aspirations of becoming doctors and renowned researchers, hopeful that their contributions to the field will have a profound impact on the well-being of both their immediate communities and populations across the globe.

Appropriately for this determined group, the framework for EYES (Figure 1) is based on sociologist Barbara Schneider's theory of aligned ambition (Arora et al., 2011; DePass and Chubin, 2017; Schneider and Stevenson, 1999). "Aligned ambition" describes strong agreement between

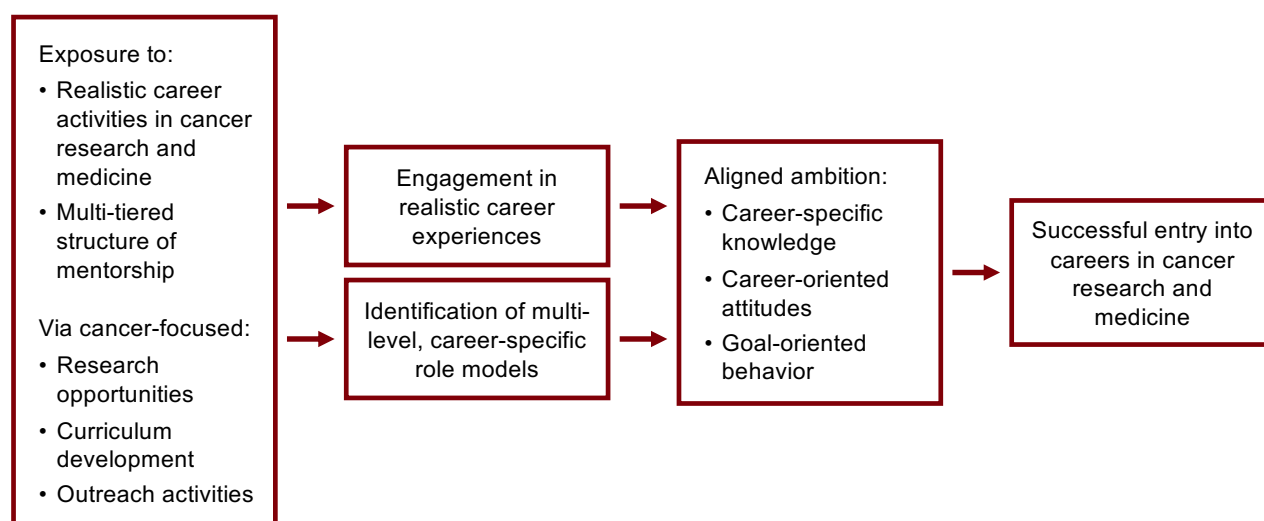


Figure 1. The theoretical framework underlying Chicago EYES on Cancer is based on sociologist Barbara Schneider's theory of aligned ambition (Schneider and Stevenson, 1999) and adapted from Arora and colleagues (2011).

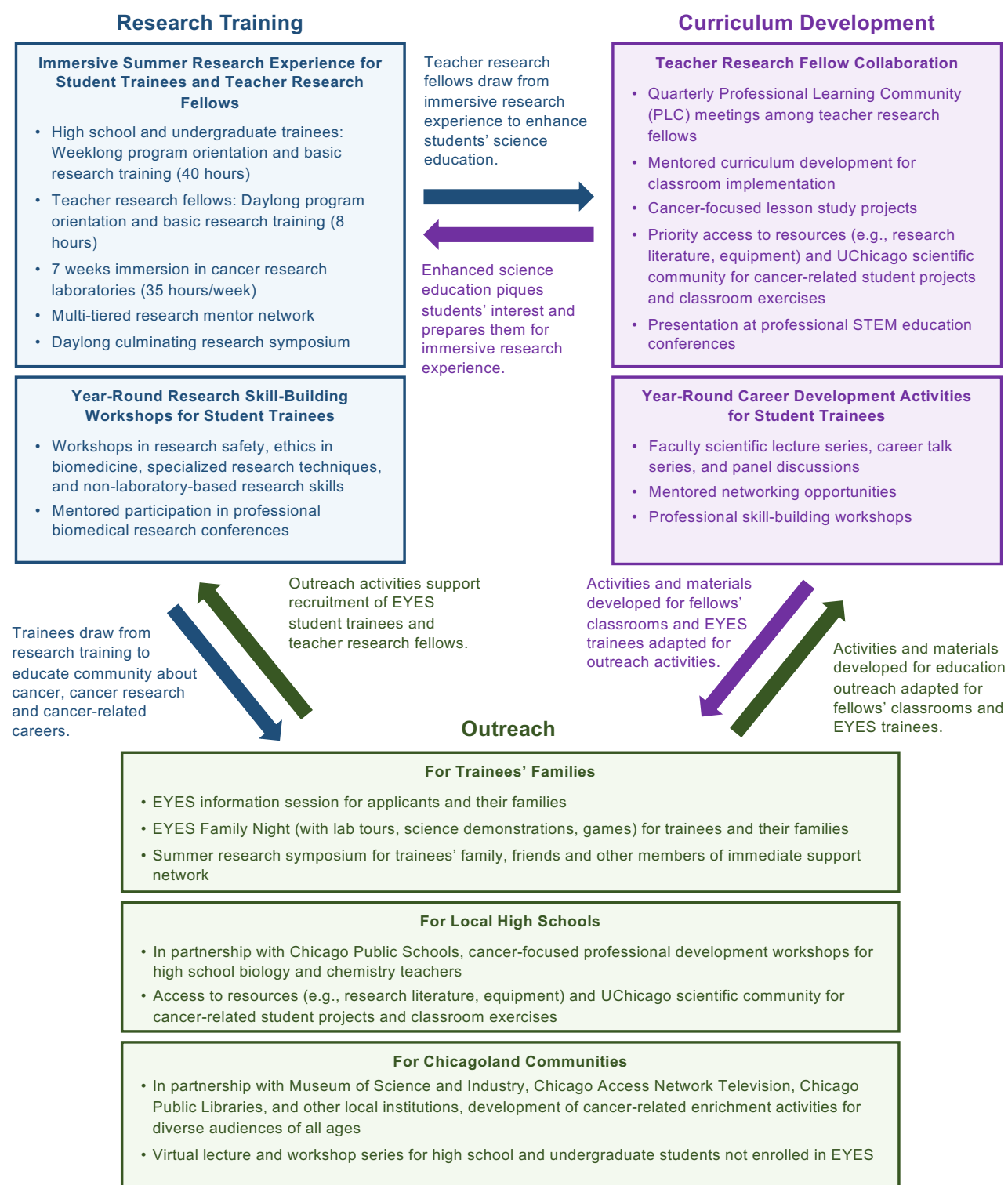


Figure 2. Core components of the Chicago EYES on Cancer program and their integration.

one's occupational goals and plans to achieve them (Sabates et al., 2011; Schneider and Stevenson, 1999). Youth with aligned ambition demonstrate more realistic and systematic approaches to pursuing career goals and successful career entry. For example, they are better able to identify which fields they plan to study in college and the institutions most likely to offer majors in that field; they are more likely to seek guidance and support when they encounter difficulty

in their coursework; and they are more likely to invest their time and effort in challenging activities that build important skills for their occupational futures (Schneider, 2009).

The theory posits three factors of aligned ambition: 1) Career-specific knowledge, such as the educational requirements of a given job; 2) Career-oriented attitudes, including realistic assessment of the challenges and rewards of adult work; and 3) Goal-oriented behavior, including engagement

in curricular and extra-curricular activities related to future careers (Schneider, 2009).

Minority students are less likely than their non-minority peers to exhibit the career-specific knowledge, attitudes, and behaviors required for aligned ambition, in large part because of their more limited access to information, resources, and role models in various career fields (Schneider, 2007, 2009). NCI YES programs have strong potential to mitigate these gaps with respect to cancer-related careers. The research experiences, curricula, and outreach supported by YES programs expose target audiences to both realistic career activities and mentorship in cancer research and medicine. Trainees' engagement in career activities and identification of career-specific role models fosters aligned ambition and, ultimately, facilitates successful career entry (Figure 1). Figure 2 summarizes the core components of the NCI YES model as realized through Chicago EYES on Cancer. We describe each in detail and share evidence of the extent to which they support career-specific knowledge, attitudes, and behaviors among EYES trainees.

EYES is a two-year program serving approximately 24 student trainees (12 new and 12 returning) and 5 teacher research fellows (up to 3 new and up to 3 returning) each year. The program is administered by a designated education team within the UCCCC, consisting of three full-time staff and a faculty member. However, implementation of most components depends on active engagement of volunteers across the university's cancer research community including faculty investigators (clinical, translational, and basic), postdoctoral fellows, graduate students, research staff, and others who contribute their time and expertise. In summer 2021 alone, more than 60 volunteers served as mentors, research supervisors, guest speakers, workshop facilitators, and symposium presentation judges, yielding a 2:1 ratio of volunteers to program participants.

Research Training. For both student trainees and teacher research fellows, research training activities are heavily concentrated during the two consecutive summer sessions, when participants are immersed in cancer research settings. Student trainees spend the first week of the summer engaged in whole-group orientation activities including requisite safety training and laboratory skills exercises. Teacher research fellows complete a comparable but abbreviated orientation on a Saturday several weeks before the start of the program. For the remaining seven weeks of the summer, participants are fully-engaged members of their respective research teams, working roughly 35 hours per week on their research projects and participating in all laboratory meetings, seminars and journal clubs as required by the faculty mentor. Their projects represent the broad spectrum of biomedical research methods and generally relate to one of four major themes: 1) molecular mechanisms of cancer; 2) cancer risk,

diagnosis and prevention; 3) precision oncology; and 4) cancer disparities. At the end of the summer, participants present their work in the form of a poster (first-year participants) or ten-minute oral presentation (second-year participants) at the culminating research symposium.

Approximately half of EYES student trainees choose to work with the same faculty mentor for both summers of the program in the interest of growing their expertise in a particular research area and strengthening relationships with members of the research team. The other half choose to broaden their expertise and professional networks by switching mentors. While either option can benefit student trainees, teacher research fellows report considerable advantages to partnering with the same research team for the duration of the program. In short, returning the second summer to a familiar research environment, where teachers can “hit the ground running” in terms of mastering protocols and scientific concepts, creates the necessary space for them to focus more intently on the development of classroom curricula inspired by their experiences. In addition, teachers have the opportunity to strengthen bonds with the faculty and research staff for further collaborations.

To support them throughout their research experiences and maintain longer-term science identity and values among trainees (Estrada et al., 2018; National Academies of Sciences and Engineering, 2019), each EYES participant is assigned a multi-level mentor network comprising the EYES leadership team, a faculty research mentor, research supervisor, peer mentor (for student trainees), and debrief captain. Peer mentors are typically UChicago graduate and undergraduate students in the biomedical sciences (including recent alumni of the EYES program), who are assigned to three EYES student trainees for regular and informal check-ins via email, text or brief in-person meetings. Debrief captains are typically postdoctoral trainees, who meet weekly with groups of 10-12 EYES participants and their peer mentors for an hourlong session. These meetings are participant-driven, intended for the exchange of revelations, frustrations, feedback and advice inspired by recent experiences with trainees' respective research teams. Time is reserved each session to facilitate progress on participants' symposium presentations, including peer review of drafted components.

To further support the development of research-based skills, student trainees and teacher research fellows participate in workshops throughout the year on such topics as research safety, ethics in biomedicine, specialized laboratory techniques, reading scientific literature, and science communication. Student trainees are also strongly encouraged to attend at least one professional conference, such as the American Association for Cancer Research, the Society for Advancement of Chicanos/Hispanics and Native Americans in Science, and the Annual Biomedical Research Conference

for Minority Students, where they present their research in a formal setting, network with scientists from around the globe, explore diverse research areas, and strengthen relationships with fellow EYES attendees and the accompanying members of the program leadership team.

Curriculum Development. As a complement to participants' research training, the EYES team has developed a diverse collection of enrichment activities to facilitate trainees' career exploration, professional skill development, and networking with peers and other members of the biomedical community. A handful of activities are required for all participants, including a faculty scientific lecture series. For the most part, however, participants are free to select those activities most aligned with their individual needs and interests. Each activity is assigned a point value based on expected time commitment and effort. All participants are required to earn a predetermined minimum number of points over the course of their summer research experience; most exceed it.

Activity offerings vary each year. They include seminars and panel discussions on such topics as non-academic research careers and women in biomedicine; interactive workshops on such skills as networking for career exploration and engaging scientific colleagues; "speed mentoring" sessions with representatives across biomedical career tracks; visits to scientific and cultural institutions, such as the DuSable Museum of African American History; and community-building events such as an ice cream social for trainees and members of their research teams. The success of EYES's COVID-19-era programming (Mekinda et al., 2021) has inspired a new repertoire of virtual activity options, giving participants unprecedented access to networks and resources across the country. This includes an ongoing skill-building and career development series offered collaboratively through the UCCCC, the University of Kentucky, and the University of Pittsburgh, connecting YES participants across the three institutions.

To facilitate curriculum development for high school science classrooms, EYES teacher research fellows meet with members of the leadership team for up to four half-day workshops each year, on weekends between October and April. The group works as a Professional Learning Community (PLC; National Academies of Sciences and Engineering, 2020) to assess existing curricular materials (HHMI BioInteractive, 2019; National Institutes of Health [U.S.] et al., 1999), test model classroom activities, and consider additional ways to leverage cancer as an anchoring phenomenon for genetics, cell biology, and other fundamental concepts in fellows' required curricula (Penuel and Reiser, 2018). EYES leadership works with fellows on an individual basis to arrange access to specialized equipment,

library resources, and members of the university's scientific community to support their teaching practice as needed.

Classroom activities developed by teacher research fellows have tended to focus on strengthening the connection between classroom learning and the professional world. For example, one teacher restructured a particular lesson as a journal club modeled after routine meetings with her summer research team. Another required students to present a classroom research project in the form of a scientific poster, using the template from the EYES research symposium. A fellow teaching a course on medical interventions invited leaders from the UChicago medical community to critique students' designs for an emergency care suite. And, a fellow overseeing her students' senior research projects enlisted postdoctoral fellows to provide personalized feedback on the proposals. These examples illustrate ways EYES teacher research fellows expand the program's capacity to support aligned ambition within the field of biomedicine, by exposing students to realistic practices and role models.

Each academic year, teacher research fellows are required to participate in at least one professional development activity to engage their colleagues at the local, regional, or national level. One of these must be a research lesson in collaboration with the EYES PLC (Takahashi and McDougal, 2016), in which fellows observe implementation of cancer-related curricula in each other's classrooms and afterward, exchange insights on the lesson's strengths and shortcomings in support of learning objectives (Rogg, 2022). Additional opportunities for fellows' professional engagement include co-facilitation of a workshop for Chicago-area science teachers on cancer as an anchoring phenomenon, or presentation of their cancer research or related curricula at the annual meeting of the National Association of Biology Teachers, the American Association for Cancer Research, or another relevant professional organization (Rogg, 2022; Rogg et al., 2019).

Education Outreach. EYES outreach activities serve three target groups: Trainees' families, local high schools, and Chicagoland communities. Outreach to families is designed to expose trainees' immediate support networks to professional research settings and scientific communities, for the purpose of increasing their understanding and support of trainees' program experience and biomedical career ambitions. Activities include EYES family night—affectionately dubbed "Time to SocialEYES" by trainees—featuring laboratory tours, research demonstrations, science-themed games and a communal dinner. Families are also encouraged to attend the culminating summer research symposium, where they can engage with members of the scientific community and attend their child's project presentation.

Outreach to local high schools is designed in close col-

laboration with Chicago Public Schools (CPS) education specialists, who oversee science curricula and teacher professional development district-wide. Based on needs identified by the specialists, the EYES team leads workshops open to all CPS secondary science teachers to support their mastery of curricular content, enrich curricular materials with insights and examples from cutting-edge science, and strengthen the connection between classroom learning and the professional science world. To date, collaborations between EYES and CPS have focused on the cancer unit in the district's new biology curriculum. In spring 2022, EYES and CPS co-hosted a daylong professional development session at UChicago for nearly 30 biology teachers. Teachers reviewed each lesson in the cancer unit with volunteers from UChicago's scientific community, who addressed content questions and related skills. Teachers also toured a cancer research laboratory and participated in a lecture about scientific advances targeting melanoma, the cancer featured as the anchoring phenomenon for the curriculum unit. EYES and CPS are planning similar collaborations on professional development for local physics and chemistry teachers.

Outreach to Chicagoland communities is driven predominantly by EYES high school and undergraduate trainees, who collaborate on cancer-related materials, presentations, and activities for diverse audiences of all ages. The purpose is to educate the broader public about cancer research, the connection between research and health outcomes, and career opportunities in the field. At the same time, EYES trainees develop valuable skills in science communication. This work is facilitated through strategic partnerships with local, public-facing institutions. Examples of EYES community outreach include trainees' participation in the Science Works STEM career day at the Museum of Science and Industry, Chicago; the development of a cancer-themed series for Chicago Access Network Television (CAN-TV) viewers (<https://www.youtube.com/watch?v=G237H-yRDTY>); and visits to Chicago Public Library branches to engage school-aged children in games about the basics of cell biology and cancer. Outreach to Chicagoland communities also includes invitations to high school and college-age students not enrolled in EYES to participate in a subset of the program's virtual activity offerings, such as the faculty scientific lecture series.

PROGRAM INTEGRATION

The strength of the Chicago EYES on Cancer model lies in strategic integration of the program's core components (cancer-focused research training, curriculum development, and outreach) to maximize reach and impact (Figure 2). Specifically, participants apply skills and insights acquired from their research experiences to the development of curriculum and outreach activities, which affirms their own learning.

Audiences for curriculum and outreach activities are introduced to key concepts and potential role models in cancer research and medicine, with the goal of encouraging interest in cancer-related careers and facilitating aligned ambition. Some audience members are inspired to enroll in the EYES program directly as student trainees or teacher research fellows, continuing the cycle.

The EYES program as a whole is becoming increasingly well-integrated within Chicago's STEM education ecosystem by strengthening partnerships with the city's educational and cultural institutions, including the Museum of Science and Industry and CAN-TV. Chief among these is Chicago Public Schools, as described above, giving EYES unique influence over curricula and instruction across the nation's third-largest public school system.

Finally, EYES is deeply integrated within the cancer research training and education initiatives of the UCCCC across the career continuum. The center runs 5 unique pathway programs, including EYES, for trainees from high school through postdoctoral fellowships. The programs are structured in such a way that individual trainees can progress from one to another for sustained and stage-appropriate skill and career development. Trainees across programs build relationships through peer mentor interactions, collaborations on community outreach projects, and UCCCC-sponsored social events, broadening trainees' support networks. Finally, EYES engages faculty, staff, and other members of UChicago's cancer research community in mentorship and outreach activities that strengthen both their competencies as educators and their sensitivities as scientists to the needs and interests of local communities.

PARTICIPANTS

To date, 46 student trainees have enrolled in EYES, including nine who completed their first year through the program's predecessor, the UCCCC's CURE program. Thirty-two have successfully finished the program. Eleven more are expected to complete all requirements by August 2022. Two trainees, who had to postpone aspects of their training due to COVID-19, will complete the program by August 2023, along with members of the incoming cohort. One trainee left the program after one summer to pursue other interests.

In selecting student trainees, EYES targets high school and undergraduate youth with established interest in science but perhaps only vague notions of career opportunities in biomedicine and limited access to pertinent guidance and support. The program admits approximately 12 new trainees each year. Consistent with the mission of the YES grant (National Institutes of Health, 2019), priority is given to those from populations underrepresented in the sciences, specifically individuals who identify as racial or ethnic minorities

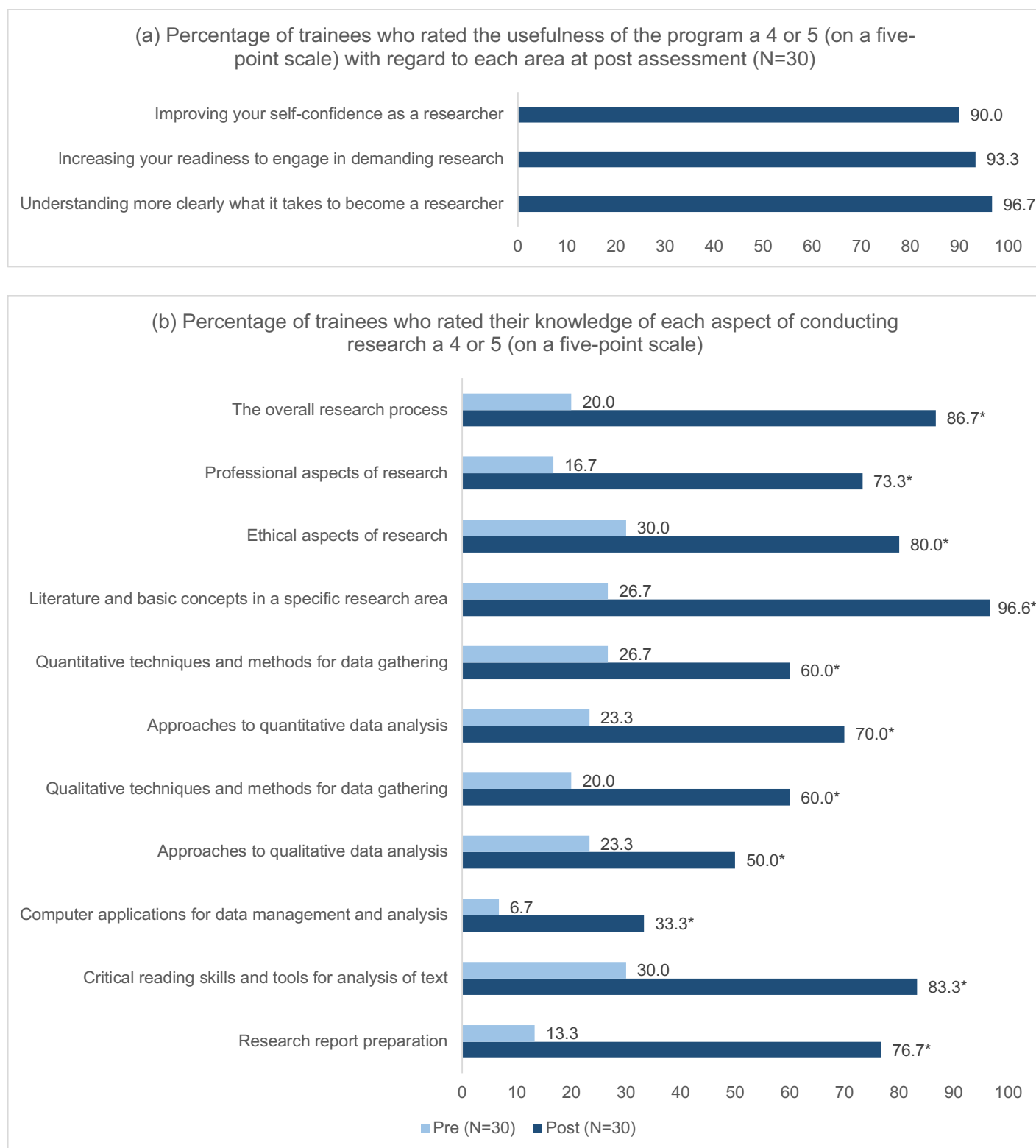


Figure 3. Initial indicators of program quality and effectiveness based on student trainees' self-reported data at time of enrollment (pre assessment) and at the conclusion of their second summer research experience (post assessment). An asterisk indicates a p-value of .001 or less.

(33/46, 71.7% of past or current trainees), economically disadvantaged (28/46, 60.9%), first-generation college (21/46, 45.7%) and/or living with a disability (1/46, 2.2%). Comparable to the applicant pools, 54.3% (25/46) of past or cur-

rent trainees were high school students at time of enrollment (versus undergraduates), and 71.7% (33/46) were female (versus other). Just 19.6% of trainees (9/46) reported previous experience in a professional research setting. At time

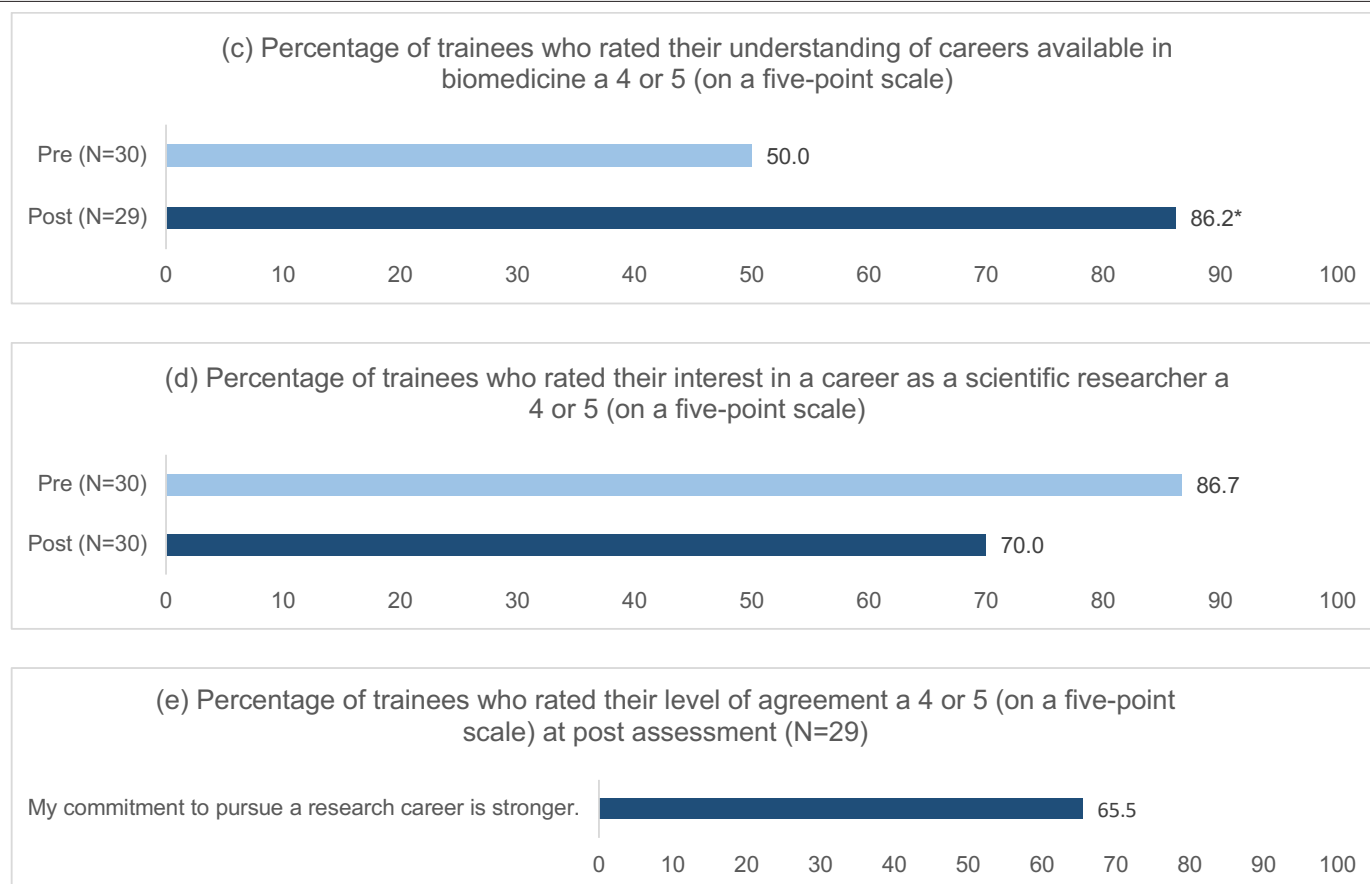


Figure 3 (continued). Initial indicators of program quality and effectiveness based on student trainees' self-reported data at time of enrollment (pre assessment) and at the conclusion of their second summer research experience (post assessment). An asterisk indicates a p-value of .001 or less.

of enrollment, all trainees expected to earn a college degree, and 82.6% (38/46) were either majoring or intended to major in a biomedicine-related field. An ambitious group, 78.3% (36/46) expected to earn a doctorate or equivalent advanced professional degree.

Teacher cohorts are deliberately small to ensure that the EYES team has bandwidth to provide personalized support for each participant, especially throughout the busy academic year. The teacher component is also more costly, with compensation at roughly three times that of student trainees. Up to four fellows are selected each year, so far from pools of no more than eight candidates (the program is demanding from teachers' perspective, too). Nine fellows have participated in the program to date, all from public schools in Chicago's under-resourced communities. They were deliberately selected to represent diverse school types (i.e., neighborhood, magnet, selective enrollment and charter), assigned curricula (i.e., Advanced Placement, International Baccalaureate, Project Lead the Way and district-sponsored), and years of experience (3-17). Eight fellows were responsible for at least one section of biology, and all but one taught additional subjects such as chemistry or anatomy and physiology. All but one fellow taught students in multiple grade levels, most commonly a combination of juniors and seniors. Three fel-

lows have successfully completed the program. Another is expected to complete the program in spring 2022 and three more in spring 2023. Two exited the program after one summer due to a career change.

ASSESSING PROGRAM QUALITY AND IMPACT: STUDENT TRAINEES

Methods. Evaluation of EYES is designed to track trainees' development and achievements over time and also to identify areas for program improvement. Data are collected through online surveys administered via REDCap at time of enrollment ("pre"; 32/32, 100% response rate) and at the conclusion of trainees' second summer research experience ("post"; 30/32, 93.8% response rate). Most measures were adopted from assessments of the Leadership Alliance Summer Research Early Identification Program (Ghee et al., 2016) and the Training Early Achievers for Careers in Health Research program (Arora et al., 2011) to facilitate meaningful comparison among research-intensive, mentor-based programs to foster diversity in the biomedical workforce. Survey items solicit information about respondents' experiences in the research setting and during organized group activities as a measure of program quality and participant

satisfaction. Survey items also measure growth in two key outcome areas: 1) research skills and expertise and 2) career knowledge and aspirations.

Presented are initial indicators of program quality and effectiveness based on a subset of data from the 30 student trainees who completed the full two-year program, and who also submitted both pre and post survey measures (Figure 3). Analyses were performed with SPSS 24 software. Values derived from Likert-type survey items were treated as ordinal (Lovelace and Brickman, 2013). Frequencies, medians and ranges were calculated for each. Related-samples Wilcoxon signed rank tests (Woolson, 2007), the non-parametric equivalent of the paired-samples t-test, were used to evaluate within-group changes over the course of trainees' program experience. The test ranks the absolute values of the differences between pre and post ratings for a given item, then compares the sums of ranks for differences with negative versus positive signs. The closer the calculated Z statistic is to zero, the more evenly the negative and positive differences are distributed, meaning less difference in ratings from pre to post. *P*-values of 0.05 or lower were considered statistically significant.

Program Quality and Trainee Satisfaction. As part of the post assessment, student trainees answered a series of Likert-type items about their experience as crude measures of program quality and participant satisfaction. Overall, their attitudes were strongly favorable, as illustrated in Figure 3a: respondents overwhelmingly felt that the program helped them understand more clearly what it takes to become a researcher (29/30, 96.7%), increased their readiness to engage in demanding research (28/30, 93.3%), and improved their self-confidence as a researcher (27/30, 90.0%).

Student trainees also completed a set of open-ended survey items, prompting them to describe their most positive and their most negative experience in the program. These data from all 30 respondents were exported to Microsoft Excel and coded thematically through inductive analysis: Preliminary descriptive codes were assigned to each participant response, descriptive codes were collapsed into thematic categories through subsequent rounds of review, and finally, the responses within each thematic category were tallied (Miles and Huberman, 1994). Responses reflecting more than one theme were co-coded as appropriate.

Interpersonal relationships emerged as a theme among trainees' most positive (16/30, 53.3%) and negative (5/30, 16.7%) experiences, suggesting the prominence of perceived social support and belonging in shaping trainees' satisfaction. Other positive themes were *personal achievements* (e.g., "Being told my contribution to my lab will help me get published on a paper!"; 10/30, 33.3%) and exposure to new areas of research, career opportunities and professional networks (9/30, 30.0%). Two additional

negative themes emerged: *unfavorable tasks*, particularly those perceived as monotonous or stress-inducing, like presenting during a research team meeting (5/30, 16.7%), and *logistical challenges*, including long commute times or computer malfunction (5/30, 16.7%). About a third of respondents reported that they had no negative experiences (9/30, 30.0%).

Research Skills and Expertise. As a measure of research skill development, student trainees rated, on a scale from 1 (None) to 5 (Very high), their knowledge of 11 aspects of conducting research. The full range of the five-point scale was used to test for change within subjects between assessment points. However, to increase readability, Figure 3b compares just the proportion of respondents at each assessment who rated items a 4 or 5, indicating self-perceptions of relatively high levels of knowledge. At time of enrollment (pre assessment), less than a third of respondents rated themselves as knowledgeable with respect to any item. By post assessment, at least half rated themselves as knowledgeable with respect to all items except computer applications for data management and analysis, for which the percentage rose from just 6.7% to 33.3%. Gains were statistically significant across the board (all *Z*s < -3.04, all *p*-values < .01).

Career Knowledge and Aspirations. At each assessment point, student trainees were asked a series of questions to gauge their level of knowledge and interest in careers in biomedicine. In particular, they were asked to rate, on a five-point Likert-type scale (1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree), the extent to which they agreed with the statement: "I have a solid understanding of the careers available to me in the field of biomedicine." The percentage of respondents who strongly agreed or agreed increased from pre (15/30, 50.0%) to post assessment (25/29, 86.2%), reflecting significant growth with regard to career knowledge over the course of the program (*Z* = -3.19, *p* = 0.001).

Student trainees were also asked to rate, on a six-point scale (1 = definitely not interested; 2 = not interested; 3 = don't know; 4 = somewhat interested; 5 = very interested; 6 = definitely interested), their interest in pursuing a career as a scientific researcher. Consistent with the self-selective nature of the program, all respondents reported initial interest, with the vast majority (26/30, 86.7%) very or definitely interested at pre-assessment. By post assessment, the percentage was 70% (21/30): 43.4% of respondents (13/30) had maintained their same level of interest, 26.7% (8/30) reported enhanced interest, and 30.0% (9/30) reported a decline; however, changes in the median rating between assessments did not reach statistical significance (*Z* = -0.63, *p* = 0.53). On an additional item administered at post assessment, 65.5% of respondents (19/29) reported that their *commitment* to

pursue a research career was stronger compared to when they started the program.

Educational and Employment Status. Data on the current educational and employment status of all 32 EYES alumni was acquired via the annual alumni survey (last administered fall 2021), direct personal contact, and LinkedIn profiles. At the time of this writing, 71.9% (23/32) were enrolled full-time in bachelor's degree programs. Eighty-seven percent (20/23) of these undergraduates were majoring in science or health-oriented fields (most commonly biology), in anticipation of careers as physicians (16/23; 69.6%), physician-scientists (3/23; 13.0%), and researchers (1/23; 4.3%). Over a third (8/23; 34.8%) planned to specialize in cancer.

Four alumni (4/32; 12.5%) were enrolled full-time in graduate degree programs: one in medical school to become a practicing physician, one in a biology-focused doctoral program to become a faculty researcher, one in a master's of nursing program to become a practicing nurse, and one in a master's of public health program to become an epidemiologist.

Four alumni (4/32; 12.5%) were employed full-time, two in research-related positions at academic institutions and two in technology-focused companies. Finally, one alumna worked part-time as a medical scribe while simultaneously applying for medical school.

Assessing Program Quality and Impact: Teacher Research Fellows. Evaluation of the teacher research fellow component has been overwhelmingly formative in nature, as the EYES leadership team adapted to the realities of collaboration within the country's third-largest public school system. EYES personnel conducted routine debrief sessions with all 9 teacher research fellows, individually and as a group, to gather information about their research experiences, plans for classroom applications and the support they desired from EYES to optimize both. An extensive debrief was conducted with the 3 members of the inaugural teacher cohort toward the end of their second year in the program to discuss program highlights, opportunities for improvement and perceived impacts on their teaching practice. The conversation was audio recorded and analyzed for key themes in fellows' reflections.

From the first days of their EYES research experience, teachers reported a renewed sense of themselves as science learners versus educators, having been plucked from their comfort zones and overwhelmed by unfamiliar scientific concepts, research methods and technologies. They described how this perspective inspired greater empathy toward their students and re-sensitized them to insecurities that might undermine students' enjoyment of science. Yet, teachers also recognized their discomfort in the laboratory as a powerful catalyst for growth, and they were eager to repli-

cate these rich opportunities for learning in their classrooms. As one teacher explained:

*Once thrown into the lab, it's like: **This** is uncomfortable, and this freaking out trying to do [the work], **this** is critical thinking. And, that has shaped how I view teaching and how I view learning. ...I let my kids struggle a lot more. ...They're doing a lot more of the heavy lifting than I am.*

By the end of the program, teachers touted their newfound confidence as science practitioners, which translated to a sense of greater "authenticity" in their teaching (Sadler et al., 2010). They cited examples of language and practice from their research experience that they incorporated into the classroom to strengthen connections to the professional scientific community. As noted above, one teacher's efforts included restructuring a lesson as a journal club modeled after her research team's weekly meetings. She described it as "a really great moment in science" and a peak in student engagement and understanding:

*To have that depth of conversation about a scientific journal article is not, like, usually it's the teacher pulling teeth, right? ...It was really, really incredible. And I don't think I would have had the capacity to do that if I had not been part of the lab. It's because I had been at the other end of that, it builds my own capacity in science. ...Then I can turn it around and flip it: How can I use it as a teacher? ...And then I told this to my students, this is what scientists **do**.*

Changes in teachers' self-perceptions as science learners and practitioners reflect potentially broad impacts of the EYES program, permeating teachers' approach to instruction regardless of a topic's relevance to cancer. Progress toward cancer-focused curricula, however, fell short of expectations for both teacher research fellows and the EYES leadership team. From the outset, teachers perceived limited flexibility to amend their assigned curricula, even as they valued cancer as an anchoring phenomenon for understanding fundamental biological concepts. Activities teachers did develop faced obstacles to implementation, for example, strict rules about building access and scheduling difficulties that prevented the EYES leadership team from providing requested support and resources. Most damaging were massive disruptions to the school calendar—the Chicago Teachers Union strike in fall 2019 and the ongoing COVID-19 pandemic—which forced the cancellation of practically all curriculum-related EYES activities for nearly two years. The EYES team has taken steps to address these challenges where possible, such as scheduling curriculum development activities more frequently throughout the year to minimize the impact of unanticipated disruptions.

DISCUSSION

Chicago EYES on Cancer empowers youth from under-represented backgrounds to pursue careers in biomedicine, while it also makes meaningful progress to enrich the practice of science teachers in under-resourced communities citywide. Student trainees reported significant growth with regard to their research skills and expertise, from specialized methods of data collection and analysis to broad concepts in research ethics and professionalism. These gains corresponded with participants' heightened sense of understanding, readiness and self-confidence with regard to research professions, and a stronger commitment to pursuing a research career. Student trainees also reported becoming significantly more knowledgeable about career options over the course of the program, insights that will help them set realistic career goals aligned with their interests and priorities. These outcomes reflect apparent gains in career-specific knowledge, attitudes, and behaviors, suggesting that the theory of aligned ambition is a suitable framework for EYES and similar programs.

The integration of teacher research fellows into the EYES program has become a natural extension of the UCCCC's well-established student-centered initiatives, with strong support from faculty research mentors and other essential contributors to EYES. Fellows reflected on their time in the program as transformational. The experience of being immersed in the laboratory setting, collaborating with members of the research team, and commiserating with student trainees over shared challenges gave fellows new insights about science learning and practice that they felt not only strengthened their skills as science educators, but also improved their ability to relate to their pupils.

Innovation. Like all YES programs, Chicago EYES on Cancer supports cancer-focused research training, curriculum development, and outreach as mandated by the NCI. The program is distinctive, however, in the integration of these core components with each other, their integration within Chicago's STEM educational ecosystem, and their integration within the UCCCC's training and education initiatives to optimize support for ambitious young people across our city.

To our knowledge, EYES is among a minority of YES programs to engage high school science teachers. In these first five years of the program's implementation, this work has evolved into a multi-pronged approach to accommodate challenges and opportunities realized through our collaboration with the nation's third-largest school district. By offering teachers both daylong professional development sessions and the full two-year, research-intensive experience, EYES is expanding access to cancer-related resources and expertise to enrich classroom learning.

Finally, the success of Chicago EYES on Cancer is reliant

on a passionate team with complementary expertise and a shared commitment to building a more diverse and equitable workforce. EYES leadership is comprised of a faculty member with extensive mentoring and research experience; an expert in positive youth development, career development, program design and evaluation; a doctoral-level cancer biologist with experience in STEM outreach; and an administrator with more than 20 years of institutional knowledge. In addition to providing direct support and mentorship to program participants, the leadership team manages a multi-tiered support network for each individual, including faculty and peer mentors as well as participants' families.

Lessons Learned. An important lesson learned through the implementation of Chicago EYES on Cancer was the overwhelming demand for programs of its kind among Chicago's diverse youth, as evidenced by consistently large application numbers. Because the UCCCC's capacity for immersive research training is limited to the number of faculty mentors available, the EYES leadership team has expanded access through more scalable activities. These include open invitation to the program's virtual faculty lecture series and skill-building workshops, and also through the development of shorter-term, less resource-intensive pathway programs that serve as potential stepping stones to EYES (see www.uchicagomedicine.org/SHE).

Additional lessons learned have centered on the EYES teacher component. Challenges undermining the translation of teachers' research experiences to classroom curricula are described above. Establishing a formal partnership with district-level leadership has proven essential, and through it, EYES now supports curriculum development and teacher professional development across Chicago public high schools. In this way, EYES has optimized its reach and accessibility to teachers, many of whom cannot commit to the intensive two-year program due to other personal and professional obligations. The partnership between EYES and CPS requires ongoing persistence and flexibility, as frequent staff turnover and district restructuring present moving targets for collaboration.

Future Plans. The early success of Chicago EYES on Cancer—and overwhelming demand for the program among Chicagoland's youth—lend support to immersive, mentorship-based research training programs as a key strategy for fostering diversity in the biomedical workforce. Plans are in place to track trainees for at least 15 years via surveys and sociable correspondence (e.g., yearly birthday emails) to assess the extent to which self-reported gains described here lead to objective progress toward careers in biomedicine, including degree attainment, employment and promotions, publications, and grants. These data are important not only to assess whether EYES promotes

successful career entry among trainees, but also to facilitate ongoing and personalized support and mentorship of program alumni. In addition to tracking student trainees, future evaluation efforts will explore secondary effects of the program via skill and career development among young people exposed to EYES curriculum and outreach activities.

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ABBREVIATIONS

CAN-TV: Chicago Access Network Television; CPS: Chicago Public Schools; CURE: Continuing Umbrella of Research Experience; EYES: Educators and Youth Enjoy Science; NCI: National Cancer Institute; PLC: Professional Learning Community; UCCCC: University of Chicago

Medicine Comprehensive Cancer Center; YES: Youth Enjoy Science

REFERENCES

- Ansell, D. (2017). *The Death Gap: How Inequality Kills*. University of Chicago Press.
- Arora, V., Schneider, B., Thal, R., and Meltzer, D. (2011). Design of an intervention to promote entry of minority youth into clinical research careers by aligning ambition: The TEACH (training early achievers for careers in health) research program. *Journal of Social Issues*, 67(3), 580–598. <https://doi.org/10.1111/j.1540-4560.2011.01715.x>
- DePass, A., and Chubin, D. (2017). Undergraduate research. *Understanding Interventions*, 8(1), 2652.
- Estrada, M., Hernandez, P. R., and Schultz, P. W. (2018). A longitudinal study of how quality mentorship and research experience integrate underrepresented minorities into STEM careers. *CBE-Life Sciences Education*, 17(1), ar9. <https://doi.org/10.1187/cbe.17-04-0066>
- Ghee, M., Keels, M., Collins, D., Neal-Spence, C., and Baker, E. (2016). Fine-tuning summer research programs to promote underrepresented students' persistence in the stem pathway. *CBE-Life Sciences Education*, 15(3), ar28. <https://doi.org/10.1187/cbe.16-01-0046>
- HHMI BioInteractive. (2019). Teaching cell biology and genetics using cancer. HHMI BioInteractive. <https://www.bio-interactive.org/planning-tools/resource-playlists/teaching-cell-biology-and-genetics-using-cancer>
- Jones, L., Estwing Ferrans, C., Polite, B., Brewer, K., Maker, A., Pauls, H., and Rauscher, G. (2017). Examining racial disparities in colon cancer clinical delay in the Colon Cancer Patterns of Care in Chicago study. *Annals of Epidemiology*, 27(11), 731–738. <https://doi.org/10.1016/j.annepidem.2017.10.006>
- Krim, J. S., Coté, L. E., Schwartz, R. S., Stone, E. M., Cleeves, J. J., Barry, K. J., Burgess, W., Buxner, S. R., Gerton, J. M., Horvath, L., Keller, J. M., Lee, S. C., Locke, S. M., and Rebar, B. M. (2019). Models and impacts of science research experiences: A review of the literature of CUREs, UREs, and TREs. *CBE-Life Sciences Education*, 18(4), ar65. PubMed. <https://doi.org/10.1187/cbe.19-03-0069>
- Lin, A. (2022). Introduction to YES programs. *Journal of STEM Outreach*, in press.
- Lovelace, M., and Brickman, P. (2013). Best practices for measuring students' attitudes toward learning science. *CBE-Life Sciences Education*, 12(4), 606–617. <https://doi.org/10.1187/cbe.12-11-0197>
- Mekinda, M. A., Domecki, M. L., Goss, K. H., and Dolan, M. E. (2021). Adapting pathway programs to the virtual world: Insights from the Chicago EYES on cancer response to COVID-19-related disruptions to training. *The Journal of STEM Outreach*, 4(3). <https://doi.org/10.15695/jstem/v4i3.07>

- Miles, M. B., and Huberman, A. M. (1994). *Qualitative Data Analysis* (2nd ed.). SAGE Publications, Inc.
- National Academies of Sciences and Engineering. (2019). *The science of effective mentorship in STEM* (A. Byars-Winston and M. L. Dahlberg, Eds.). The National Academies Press. <https://www.nap.edu/catalog/25568/the-science-of-effective-mentorship-in-stemm>
- National Academies of Sciences and Engineering. (2020). *Changing expectations for the K-12 teacher workforce: Policies, preservice education, professional development, and the workplace* (R. Floden, A. Stephens, and L. Scherer, Eds.; p. 195). The National Academies Press. <https://doi.org/10.17226/25603>
- National Academies of Sciences, Engineering, and Medicine. (2017). *Undergraduate Research Experiences for STEM Students: Successes, Challenges, and Opportunities*. The National Academies Press. <https://doi.org/10.17226/24622>
- National Institutes of Health. (2016). *National Cancer Institute Youth Enjoy Science Research Education Program (R25)*. <https://grants.nih.gov/grants/guide/pa-files/par-17-059.html>
- National Institutes of Health. (2019). *Notice of NIH's interest in diversity (Notice NOT-OD-20-031)*. Author. <https://grants.nih.gov/grants/guide/notice-files/NOT-OD-20-031.html>
- National Institutes of Health. (2021). *National Cancer Institute Youth Enjoy Science Research Education Program (R25 Clinical Trial Not Allowed)*. <https://grants.nih.gov/grants/guide/rfa-files/RFA-CA-21-020.html>
- National Institutes of Health (U.S.), Biological Sciences Curriculum Study, Videodiscovery, Inc., and National Cancer Institute (U.S.). (1999). *Cell biology and cancer* (NIH Publication No. 10-4646).
- Penuel, W. R., and Reiser, B. J. (2018). *Designing NGSS-aligned curriculum materials*. Committee to Revise America's Lab Report, 1–51.
- Rauscher, G., Allgood, K., Whitman, S., and Conant, E. (2012). Disparities in screening mammography services by race/ethnicity and health insurance. *Journal of Women's Health*, 21(2), 154–160. <https://doi.org/10.1089/jwh.2010.2415>
- Rogg, S. (2022, April 8). *A cancer case study storyline and research lesson*. Wisconsin Society of Science Teachers Annual Conference, Rothschild, WI.
- Rogg, S., Mekinda, M., and Scarlett, L. (2019). *Logic model conceptualization of teacher research in Chicago EYES on Cancer* [Poster]. National Association of Biology Teachers 2019 Professional Development Conference, Chicago, IL.
- Sabates, R., Harris, A., and Staff, J. (2011). Ambition gone awry: The long-term socioeconomic consequences of misaligned and uncertain ambitions in adolescence. *Social Science Quarterly*, 92(4), 959–977.
- Sadler, T., Burgin, S., McKinney, L., and Ponjuan, L. (2010). Learning science through research apprenticeships: A critical review of the literature. *Journal of Research in Science Teaching*, 47(3), 235–256. <https://doi.org/10.1002/tea.20326>
- Sadler, T., and McKinney, L. (2010). Scientific research for undergraduate students: A review of the literature. *Journal of College Science Teaching*, 39(5).
- Schneider, B. (2007). *Forming a college-going community in US public high schools*.
- Schneider, B. (2009). Inspiring youth to careers in science and medicine: Lessons from the Sloan study of youth and social development. *Journal of Public Health Management and Practice*, 15(Supplement), S102–S106. <https://doi.org/10.1097/PHH.0b013e3181be0031>
- Schneider, B., and Stevenson, D. (1999). *The Ambitious Generation*. Yale University Press.
- Sighoko, D., Hunt, B., Irizarry, B., Watson, K., and Ansell, D. (2018). Disparity in breast cancer mortality by age and geography in 10 racially diverse US cities. *Cancer Epidemiology*, 53, 178–183. <https://doi.org/10.1016/j.canep.2018.02.003>
- Takahashi, A., and McDougal, T. (2016). Collaborative lesson research: Maximizing the impact of lesson study. *ZDM*, 48(4), 513–526. <https://doi.org/10.1007/s11858-015-0752-x>
- University of California Berkeley. (2021, October 11). *Most to least segregated cities in 2020*. Othering and Belonging Institute. <https://belonging.berkeley.edu/most-least-segregated-cities-in-2020>
- Woolson, R. (2007). Wilcoxon signed-rank test. In *Wiley encyclopedia of clinical trials* (pp. 1–3).