HHS Public Access

Author manuscript

Genet Med. Author manuscript; available in PMC 2021 March 15.

Published in final edited form as:

Genet Med. 2021 January ; 23(1): 222–229. doi:10.1038/s41436-020-00962-5.

The NHGRI Short Course in Genomics: Energizing genetics and genomics education in classrooms through direct engagement between educators and scientists

Sarah M. Robbins, PhD[1,2], **Christina R. Daulton, MA**[1], **Belen Hurle, PhD**[1], **Carla Easter, PhD**[1]

[1]Education and Community Involvement Branch, National Human Genome Research Institute, National Institutes of Health, Bethesda, MD 20892

[2]American Society of Human Genetics, Rockville, MD 20852

Abstract

Purpose: The National Human Genome Research Institute (NHGRI) at the National Institutes of Health (NIH) recognizes an urgent need for educator resources on cutting-edge scientific topics due to increased public interest in genetics and genomics. We developed a Short Course in Genomics ("Short Course") to inspire new teaching materials through collaborative course development sessions and lectures, to expand access to cutting-edge scientific information, and to provide a framework to consider when crafting new coursework related to scientific education.

Methods: We compared publicly available participant data from 2015 to 2019 to data from the National Center for Education Statistics to assess our progress in serving diverse educator and student populations. We also evaluated course agendas and interviewed participants and instructors.

Results: Middle School, High School, Community College, and Tribal College course attendees from the last five years were more likely to teach students from diverse communities underrepresented in STEM. Both attendees and Short Course instructors emphasized the importance of bidirectional learning through interactive curriculum development.

Conclusions: This course has the potential to facilitate the engagement of educators and students at all levels, recruit and maintain a diverse STEM workforce, and improve genomic literacy and future health decision-making.

Keywords

Education; STEM workforce; genomic literacy; curriculum development; diversity

CORRESPONDENCE: Carla Easter, easterc@mail.nih.gov, 301-594-1364.

AUTHOR'S CONTRIBUTIONS

CE provided overarching direction and oversight to Short Course and served as a liaison to the communities and to the NIH leadership. BH and CD co-lead Short Course since 2016. SR, BH, and CD performed and transcribed interviews. SR performed all analyses and drafted the manuscript. All authors read, edited, and approved the final manuscript.

Conflicts of Interest: All authors assert that they have no conflicts to disclose.

INTRODUCTION

In 1990, the Human Genome Project was announced. Its goal was to produce the first map and sequence of the human genome. This ambitious international project was estimated to cost over $1 billion USD. In 1997, the small National Center for Human Genome Research at the National Institutes of Health (NIH) was elevated to the status of research institute and renamed the National Human Genome Research Institute (NHGRI) with the charge to lead this historic and large-scale effort [1]. By 2003, the first draft sequence of the human genome was completed, under budget and ahead of schedule. Prior to the 21st century, laboratory genetics and genomics remained largely a research tool with little applicability to routine medical practice. However, within the last 15 years, research in genetics and genomics has accelerated considerably as the human genome was studied letter by letter. The general public can now readily access their genetic information through next-generation sequencing technologies and genotyping arrays in both medical and direct to consumer settings.

Utilization of new techniques into medical practice requires not only rigorous supporting evidence, but also education initiatives and preparation for all individuals involved in healthcare decisions. Innovative public education is necessary to address the new and continually evolving knowledge gaps in genetics and genomics. Genomics is a crucible of discovery and has the power to transform modern medicine. Thus, it is imperative for the public to be genomically literate to make informed health decisions for themselves and their families. It is equally imperative for K-16 students to have access to potential genomic careers in order to actualize the benefits of genomics in the full range of American communities. Although implementation of genomic medicine into routine healthcare is still a work in progress, direct-to-consumer (DTC) genetic testing has brought genetics and genomics into the households of tens of millions of Americans [2]. With a projected global market of over $310 million by 2022, DTC testing is expanding exponentially [3]. Consumer interpretation of direct-to-consumer tests necessitates a basic understanding of genetics and genomics [4,5].

Current Gaps in Genomics Education.

Previous efforts to address gaps in science education have worked to standardize the basic principles taught in grades K-12, such as through the Next Generation Science Standards (NGSS). Since their development in 2013, the NGSS have been adopted by 20 states, with 24 other states using similar frameworks for their own standards development [6]. The NGSS aims to educate all students, including those from diverse backgrounds currently underrepresented in science, technology, engineering, and math (STEM) fields, such as Latinx, African American, Pacific Islander, Native Hawaiian, American Indian, or Alaska Native students, students with disabilities, students from disadvantaged economic regions, and first-generation students [7]. A focus on equitable education requires teaching all students the skills they need to succeed, as defined by the National Research Council's Framework for K-12 Education [8]. However, cutting-edge technologies and techniques, like gene editing or single molecule DNA sequencing, are not currently integrated into science curriculum standards. Relevant and exciting material is needed to engage students in

scientific thinking and encourage them to consider careers within the STEM workforce. New hands-on activities and curricula must incorporate skill-building, in addition to conveying information about scientific phenomena.

Foreseeing that genetic based health and ancestry information would soon to be widely available, NHGRI recognized that there would be an urgent need to educate and engage the public about genomics and genetics. To provide a platform that would enable the testing of experimental education practices, NHGRI began the Short Course in Genomics in 2003. The course was initially designed to update post-secondary biology faculty, as well as other instructors, researchers, and students in related disciplines, on genomic science. Though the Short Course began almost two decades ago, it has continued to evolve. The most recent form of the Short Course began in 2015 with a small pilot class of 10 teachers. The four-day course offers middle school, high school, community college, and Tribal College teachers the opportunity to travel to the NIH headquarters in Bethesda, Maryland for interactive curriculum development and cutting-edge lectures from researchers, clinicians, and staff. The Short Course highlights a range of genetics and genomics topics, including sequencing technologies, bioinformatics, basic and translational research, gene editing, the human microbiome, and ethical issues in genomics research (for a sample program, see Supplementary Materials 1). Although focused on genetics and genomics, this course could be used as a framework for curriculum development in any rapidly growing STEM field. Importantly, the Short Course reaches educators nationwide, with a focus on those who teach students largely underrepresented in the STEM workforce. The interactive environment also offers a unique opportunity for scientists to connect with and learn from educators teaching our future generation of scientists, healthcare practitioners, patients, and science consumers. Here we describe the best practices and areas for growth of NHGRI's Short Course in Genomics. This course aims to bridge the current gaps in genomics education by providing a forum for educators to explore new scientific discoveries, to learn directly from researchers, and to interactively build new curricula and activities tailored to engage students at all levels, from all cultures, regions, and perspectives. The Short Course in Genomics, further detailed below, introduces professional development and cutting-edge educational content at multiple levels of the educational spectrum and across diverse student populations, with a focus on the most underserved. This multidimensional framework based on multiple, concomitant entry points can be used by any program intending to quickly broaden educational access in any rapidly growing scientific field, like genetics and genomics.

MATERIALS AND METHODS

Ethics Statement.

We obtained consent for all interviews conducted, including media release and consent to be identified in this manuscript. This study does not meet the definition of human subjects research and therefore does not require IRB review and approval; this determination was approved by the Office of Intramural Research at the National Institutes of Health.

Recruitment of Potential Course Attendees.

A flagship component of the Short Course is the conscious effort placed on targeting educators who serve diverse student bodies and those who do not have easy access to cutting-edge educational experiences (Table 1). The course was advertised on the NHGRI homepage and through NHGRI social media. To better target the most underserved, the information about the application process was disseminated through community partners, Short Course alumni, and directly by email to department chairs of schools and colleges that traditionally serve students underrepresented in STEM. Such distribution mailing lists were updated yearly to ensure that the schools continue to receive the information regardless of staff turnover. Educators from around the country and the U.S. territories applied in order to be considered for the Short Course. Applications included information about subjects taught, home institution, and other demographics (Table 1). Short answer portions of the application allow educators to demonstrate their need for in-depth learning in genomics and hands-on material development. Applications were reviewed by a diverse panel of NHGRI staff representing different divisions and offices across the NHGRI (Table 1). This inclusive approach promotes institutional support and buy-in. The Course was free for attendees; travel and housing accommodations support were not typically provided. However, to increase the outreach to underserved communities, applicants serving communities underrepresented in STEM careers were eligible for a small pool of travel funding. Typically, about one-third of applicants were accepted into the Short Course, with travel support offered to 4-6 participants per year.

Comparison between Course Data and Publicly Available School Data.

To appraise our progress in serving diverse educator and student populations, we reviewed course agendas and attendee records, including application materials, from 2015 to 2019 and interviewed participants and NIH Short Course instructors. We compared publicly available enrollment data from the Short Course in Genomics from 2015 through 2019 to data from the Next Generation Science Standards (NGSS) website (https://www.nextgenscience.org/) and the National Center for Education Statistics (NCES) (https://nces.ed.gov/). We collected information on what states were participating in NGSS. From the NCES, we used national surveys on student demographics, lunch program eligibility, and Pell Grant status including: Common Core of Data 2017-2018 Membership (version 1a), Common Core of Data 2017-2018 Lunch Program Eligibility (version 1a), Integrated Postsecondary Education Data System 2017 Student Financial Aid and Net Price, and Integrated Postsecondary Education Data System 2017 Fall Enrollment (revised October 2019). Using custom scripts, we compared data for all schools and/or community colleges to Short Course schools in R. We plotted data using the packages ggplot2 and usmap [9, 10]. We also conducted interviews with eight Short Course participants, three trainee volunteers, and seven expert lecturers. Interviews with Short Course faculty and trainees were selected by the number of years of involvement in the course as well the level of engagement with participants. Interviews with Short Course participants were selected by the following: 1) educational sector/level to ensure adequate representation between middle schools, high schools, community colleges, and Tribal Colleges; 2) regional distribution; and 3) desire to be interviewed. The length of the interviews ranged from 20 minutes to 1 hour. The same questions were given for all faculty and participants, respectively. Transcription of interviews was performed as a service

by National Capitol Contracting or by the authors. We edited some quotes for clarity or wording.

Collection of Short Course Materials and Evaluation.

We collected Short Course agendas from 2015 through 2019 and determined topics, format, and staff composition for each session within the five-year period (Figure 1). We plotted this information in R using the package ggplot2. Importantly, the Short Course involves not only didactic sessions, but also hands-on learning and curriculum development (Figure 1A). Non-NIH partners, Short Course alumni, and volunteers (typically NIH Intramural Research Program trainees) also contribute to the success of the course (Figure 1B). The organizers of the Short Course invite experts from the NIH Intramural Research Program to present lectures that cover topics such as sequencing technologies, brain and behavior, newborn sequencing, bioinformatics, gene editing, the human microbiome, and ethical issues in genomics research (Figure 1C).

RESULTS

Background of Short Course Attendees.

Teachers came to the Short Course from middle schools, high schools, community colleges, and Tribal Colleges across the country and had a range of teaching experience (Figure 2B-2D). Educators most often taught biology or life science classes, though most had experience teaching more than one STEM class (Figure 2E). A STEM background was not strictly required; three Short Course attendees reported having primary teaching duties in either English, English as a Second Language, or Reading (Figure 2E).

Short Course Agendas from 2015-2019 Reveal Growing Research Areas and Successful Structures.

We found that course format and contributors stayed relatively the same over the five-year-period, while course content and lecture subjects varied as scientific fields of interest changed (Figure 1A-1C). Traditional, keynote-style, lectures by NIH intramural researchers occupied a steady 50-60% of course time from 2015-2019 (Figure 1A). Different levels of alumni participation represent the natural evolution and maturity of the Short Course, which grows in its capacity to provide an extended experience; the highest level of alumni participation was recorded in 2019 with the presentation of three new alumni-led lesson plans (Figure 1B). Clinical and translational research, as well as bioinformatics, saw the most growth in representation in course lecture content throughout the five-year period of this course assessment (Figure 1C).

Comparison to State Adoption of the Next Generation Science Standards and Metrics from the National Center for Education Statistics Acts as a Proxy for Populations Served by the Short Course Participants.

To determine the demographics of schools that employ Short Course teachers, we used publicly available data from the National Center for Education Statistics, including the Common Core of Data (CCD) and the Integrated Postsecondary Education Data System (IPEDS) to assess if recruitment efforts were successful in reaching educators from schools

with students underrepresented in the sciences. We found that Short Course educators taught at schools that were more likely to serve students underrepresented in science, especially American Indian, Alaska Native, Hispanic/Latinx, and Black or African American students, compared to all colleges in IPEDS (including community and Tribal Colleges) and all middle and high schools in CCD and compared to all IPEDS community colleges (Figure 2A). Middle and high schools with Short Course attendees were not significantly more likely to have free or reduced-price lunch programs (Figure 3B). Conversely, colleges where Short Course attendees taught received significantly more Pell grant funding, despite approximately the same number of grants (Figure 3C, 3D).

Interviews Highlight Most Impactful Practices of the Short Course.

All interviewees were highly positive about the impact of the Short Course; even when expressly asked for improvements, most only recommended sharing the course with more people. Educator attendees often connected their learning experience to that of their students. Samantha Agoos, a teacher at Denver East High School in Denver, Colorado, emphasized the importance of new and topical training for educators, saying, “I’m doing a disservice to my students if I’m not the most up-to-date on research, because I think that part of my job is also imparting them with an authentic culture of science.” Andrew Lee, an adjunct associate professor at the Northern Virginia Community College in Annandale, VA shared, “The fun is to go in and be willing to meet people, exchange ideas, because by design, it’s a self-selected group of people who are interested in learning and exchanging, and personable people doing cool things. I also recommend people coming to it with a list of problems or obstacles in their classroom environment, things they want to improve on as far as becoming better teachers, and then perhaps also bringing something unique about their school district, university, college, to share or develop further by bouncing those ideas off of their participants.” Karla Fuller, an assistant professor at the City University of New York in New York City, NY, highlighted the importance of representation: “I decided to focus on teaching because I realized that there are not a lot of scientists that look like me, and so the more students that I can see -- that I can show that scientists look different, maybe the more students will consider seeing themselves as scientists.”

Expert lecturers and volunteers also benefited from interacting with Short Course attendees. Sara C. Hull, the Director of the NIH Bioethics Core, conveyed that the Short Course “… takes what I’m doing, which sometimes feels very obscure, and it helps me feel like it’s relevant… That actually brings even more meaning to my work. I think we have a responsibility at the NIH to bring all of the good work that we do to as diverse populations as possible.” Trainee volunteers mentioned that volunteering in the Short Course gave them the opportunity to explore a future career in teaching and science administration, while also having the rewarding opportunity to share their training at NIH. Together with interviews of Short Course attendees, volunteers, and expert lecturers, we developed a list of best practices of the Short Course (Table 2).

Interviews with Short Course instructors, participants, and attendees also highlighted some areas for growth (Table 2). Though interviewees were highly positive, many expressed interest in sharing the benefits of the Short Course among a wider audience. For instance,

interviewees were interested in strategies to scale up the course, with many expressing interest in a “Virtual” Short Course, where material could be shared online with video lectures. Interviewees also emphasized the benefits of replicating the course at locations beyond the NIH headquarters or expanding cohort size, though many recognized the increased programmatic support needs for this expansion. Continued recruitment of teachers from underresourced communities and communities underrepresented in STEM was an important goal that was also highlighted as a potential area for growth, which could be aided by increased travel funding.

DISCUSSION

Through our assessment, we highlight the many successes and some areas of improvement for a genetics and genomics course for educators. The success of the Short Course rests on three pillars. First and foremost, the Short Course features cutting-edge genomic science that is constantly updated and presented in a variety of learning formats. Second, participants and Short Course faculty have an equal partnership, resulting in diversity of thought, bi-directional learning, and professional empowerment for all involved. Lastly, sustainability is achieved through well-developed community networks and long-term partnerships with a focus on recruiting and retaining educators who serve the underserved: rural communities, schools with high percentages of students receiving free and reduced lunch, students receiving Pell Grant funding, and schools serving very diverse communities. Through our retrospective analysis, we confirmed that our targeted efforts to recruit highly motivated teachers who are embedded in underserved and underrepresented communities was successful (Figure 3).

Connecting Educators to the Cutting Edge

Short Course developers constantly incorporate new topics based on both the latest genomic science trends and the feedback provided by the participants in post-attendance evaluation surveys. Lecturers are encouraged to update their talks every year with new details about their research, and they are directed to tailor their presentations for an audience of educators with bachelor’s, master’s, and doctoral degrees in scientific fields. Discussion time is built into the course curriculum to allow teachers to build networks and learn from each other. Even though instructors teach students at a range of levels, sharing best practices is a highlight for many attendees. After taking the course, the educators are empowered to tailor the information, studies, and perspectives discussed to the level and needs of their respective audiences – from middle school to community college. By connecting with experts in person, educators form a network with scientists, giving them a resource for their own lectures and courses at their home institutions. This collaborative process leads to the permeation of cutting edge science throughout multiple levels of the educational spectrum, simultaneously.

The course strives to frame scientific and societal topics found in news and current events in ways that promote critical thinking, dialogue, and student engagement. For instance, direct-to-consumer (DTC) testing is explored by analyzing research on how genetic ancestry companies construct claims about the relationship between genetic ancestry and Native

American identity and the possible sociopolitical ramifications of DTC testing for tribal communities [11].

The program also includes interactive workshops and hands-on activities that go beyond traditional, keynote-style, lectures. For example, in 2017, NIH Intramural Research Program trainees created a hands-on activity to demonstrate how the CRISPR/Cas9 gene editing system could be used to cure sickle cell anemia. The activity is offered as ready-to-print pdfs and paired with an educator's guide and a deck of slides to aid instruction. Of note, this activity pre-dated the first clinical trials attempting to treat sickle cell disease using CRISPR/Cas9 in 2019 [12]. In the three years since its debut, the activity has been offered in eleven NHGRI STEM events with over 550 high school students, teachers, and adult attendees. With their new hands-on knowledge, learners can now follow, in real time, the wave of studies moving CRISPR/Cas9 gene editing out of the lab and into clinical trials.

Finally, educators can not only learn from top researchers, but can also see and touch innovative technologies. For example, participants tour the state-of-the-art NIH Intramural Sequencing Center, which houses next-generation sequencing machines [13]. The NIH Intramural Sequencing Center experts demonstrate current genome sequencing technology and compare to common practices employed at the time of the Human Genome Project. Many educators, especially those from institutions with limited resources, do not have access to this expensive equipment at their home institutions, but can share first-hand experience and photos with their students.

Professional Benefits at All Levels

Wide institutional buy-in is essential to Short Course efforts. Hands-on investment by NIH senior lecturers gives leadership a detailed and personal view of the interests of the public about genomics, which is integral to making certain that all communities have access to and understanding of genomics. During question and answer sessions, senior lecturers learn from educators about the most important sociocultural issues in their communities, highlighting emerging priorities; they recognize that Short Course instructors have first-hand knowledge of their students' needs. Junior researchers and trainees also benefit by practicing professional skills; postbaccalaureate and postdoctoral trainees from the NIH intramural research program volunteer to coordinate tours, instructor schedules, and hands-on activities. Trainees help guide discussions with their recent experience as a biology or genetics students. The interactive format of the course offers a unique opportunity for scientists in training to connect with and learn from educators teaching the future generation of scientists, healthcare practitioners, patients, and science consumers. By volunteering, trainees also gain unique experience in project management, research coordination, education, and community engagement. For instance, Short Course intramural trainees with no previous programmatic or administrative experience have successfully transitioned to an array of non-bench careers in places such as the AAAS Science and Technology Fellowship, the NIH Center for Scientific Review, the NIH "All of Us" Initiative, and the NASA Translational Research Institute for Space Health.

From the perspective of the attendees, the Short Course not only benefits the participating educators, but directly impacts their student populations as well. Interventions, such as the

Short Course, which reach teachers educating students before they pursue studies at a four-year institution, have the potential to ignite an early interest in STEM careers and improve access to training experiences. Short Course participants have successfully referred their students to training programs at the NIH, such as the Summer Program Internship (https://www.training.nih.gov/programs/sip) [14, 15, 16] and the Postbaccalaureate Program (https://www.training.nih.gov/trainees/postbacs).

Opportunities for Continuing Partnerships and Equitable Resource Sharing

Importantly, the Short Course in Genomics is only the beginning of a relationship between educators and NHGRI. Question and answer sessions and networking opportunities during the course have allowed attendees to communicate their needs to NHGRI faculty and staff. A sustained effort is made to connect teachers from different Short Course cohorts. For instance, in subsequent years after their initial participation, local alumni are encouraged to attend Short Course lectures, tours and socials. Also, Short Course collaborative projects often include participants who - despite attending the course in different years - can connect with each other and work together on their shared interests.

Multiple projects and initiatives grew from collaborations with Short Course alumni, including the Tribal College Consortium on Genomics Training (TCCGT) and lesson plan development groups in the areas of bioinformatics, the human microbiome, and gene editing inspired by Short Course lectures and content. NHGRI also actively works to promote the leadership, high level teaching, and innovation of Short Course alumni at highly visible and nationally attended venues, including presentations at the American Society of Human Genetics meeting in October 2019 and acceptance at the 2020 South by Southwest EDU (SXSW EDU) Conference and Festival. Local teachers often return to the NIH campus during the school year for tours with their students, host NIH scientists in their classrooms, and serve as advisors for educational initiatives in bi-directional collaborations that often span multiple years. Continued engagement with educators and their communities is crucial to the success of genomics education nationwide, as well as the fulfillment of NHGRI's mission.

Sharing the expert knowledge of NIH investigators and the larger scientific community with educators directly impacts classrooms and communities. Through their teachers experiences and knowledge gained through the Short Course, students increase their genomic literacy, which in turn informs their own health decisions in the future. NHGRI's Short Course in Genomics can serve as a framework for the creation of topical and cutting-edge new materials that engage students at all levels, from all cultures, regions, and perspectives. In a reciprocal exchange, NIH investigators are educated about the diverse needs of teachers, students, and the larger public, which informs their research. Public engagement and genomic literacy efforts, such as the Short Course, are integral to NHGRI's vision of improving the health of all humans through advances in genomics research and ensuring the benefits reach all of humankind. Educating and recruiting a diverse STEM workforce in the ever-evolving field of genomics provides a pathway to achieve this vision.

While the Short Course focuses on genomics, the framework and lessons are transferrable. NHGRI's Short Course has been an innovative leader in genomic education; however, other

institutions, especially those with active research programs, would be well-suited to replicate and pursue similar educational programs. Incorporation of Short Course best practices, such as dynamic lectures and interactive activities, networking opportunities for attendees among themselves and investigators, and continued relationship building with educator communities, particularly from underrepresented populations in STEM, will enrich future outreach and education efforts.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

ACKNOWLEDGEMENTS

We thank Lawrence C. Brody and Sarah C. Hull for their critical review of the manuscript and for insightful discussions; and the two anonymous reviewers for their helpful feedback; Elizabeth Tuck, Faye A. Brown, Sherese B. Teixeira, Zelia F. Worman, and Kelly Hudspeth for their recruitment, organizational and administrative contributions; James R. Thomas, James C. Mullikin, and Alice C. Young for facilitating the NIH Intramural Sequencing Center tour; and Eric D. Green, the NHGRI director, for supporting the Short Course as a mechanism to increase genomic literacy.

We also thank the community of educators that have participated in Short Course over the years: in particular, Karla Fuller, Andrew Lee, and Joseph Wilcox. The success of Short Course hinges on the many dedicated NIH lecturers, intramural trainees, technicians, and staff who have volunteered over the years as teaching assistants and application reviewers, especially Erin A. Jimenez for leading the creation of the CRISPR-Cas9 activity. We would also like to thank all the community partners who have enriched the program activities.

Funding: This work was supported by the NHGRI Intramural Research Program.

REFERENCES

1. NHGRI History and Timeline of Events. National Human Genome Research Institute. https://www.genome.gov/about-nhgri/Brief-History-Timeline. Accessed 9/30/19.
2. Manolio TA, Chisholm RL, Ozenberger B, Roden DM, Williams MS, Wilson R, Bick D, Bottinger EP, Brilliant MH, Eng C, Frazer KA, Korf B, Ledbetter DH, Lupski JR, Marsh C, Mrazek D, Murray MF, O'Donnell PH, Rader DJ, Relling MV, Shuldiner AR, Valle D, Weinshilboum R, Green ED, Ginsburg GS. 2013 "Implementing genomic medicine in the clinic: the future is here." Genet Med, 15(4):258–267. Doi:10.1038/gim.2012.157. Accessed at: https://www.ncbi.nlm.nih.gov/pubmed/23306799 [PubMed: 23306799]
3. Kalorama Information. "The Market for Direct to Consumer Genetic Health Testing." Accessed at: https://kaloramainformation.com/product/the-market-for-direct-to-consumer-genetic-health-testing/
4. McGuire AL, Evans BJ, Caulfield T, Burke W. "Regulating Direct-to-Consumer Personal Genome Testing." Science, 330(6001), 181–182. Doi: 10.1126/science.1194006. Accessed at: https://science.sciencemag.org/content/330/6001/181.long
5. Carere DA, Kraft P, Kaphingst KA, Roberts JS, Green RC. "Consumers report lower confidence in their genetics knowledge following direct-to-consumer personal genomic testing." Genet Med, 18(1): 65–72. Doi: 10.1038/gim.2015.35. Accessed at: https://www.ncbi.nlm.nih.gov/pubmed/25812042
6. National Science Teaching Association. "About the Next Generation Science Standards." https://ngss.nsta.org/About.aspx. Accessed 10/10/19.
7. Ghattas NI, Carver JS. 2017 "Cultural Responsiveness of the Next Generation Science Standards." Journal of STEM Teacher Education, 52(1): 17–30. Doi: 10.30707/JSTE52.1Ghattas
8. Infographic: Essential Practices for K-12 Science Classrooms. The National Academies Press https://www.nap.edu/visualizations/practices-for-k-12-classrooms/.
9. Wickham H 2016 Ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag, New York.

10. Di Lorenzo P 2019 “Package ‘usmap.’” Accessed at: cran.r-project.org/web/packages/usmap/usmap.pdf
11. Walajahi H, Wilson DR, Hull SC. Constructing identities: the implications of DTC ancestry testing for tribal communities. Genet Med. 2019;21(8):1744–1750. doi:10.1038/s41436-018-0429-2 [PubMed: 30662065]
12. Demirci S, Leonard A, Haro-Mora JJ, Uchida N, and Tisdale JF. 2019 “CRISPR/Cas 9 for Sickle Cell Disease: Applications, Future Possibilities, and Challenges.” Adv Exp Med Biol, 1144: 37–52. Doi: 10.1007/5584_2018_331. [PubMed: 30715679]
13. NISC: NIH Intramural Sequencing Center. https://www.nisc.nih.gov/services.htm. Accessed 10/10/19.
14. Local Student Interns at the National Institutes of Health. The Vail Voice, 9 4, 2018 http://www.thevailvoice.com/local-student-interns-at-the-national-institutes-of-health/
15. TMCC Student Completes NIH Internship. Truckee Meadows Community College,9 10, 2019 https://www.tmcc.edu/news/2019/09/tmcc-student-completes-nih-internship
16. Pathways for Indigenous Students: One Tribal College Student's Journey, Tada Vargas. National Human Genome Research Institute, 5 11, 2020 https://youtu.be/jTXKKCvn9jk (11:51)

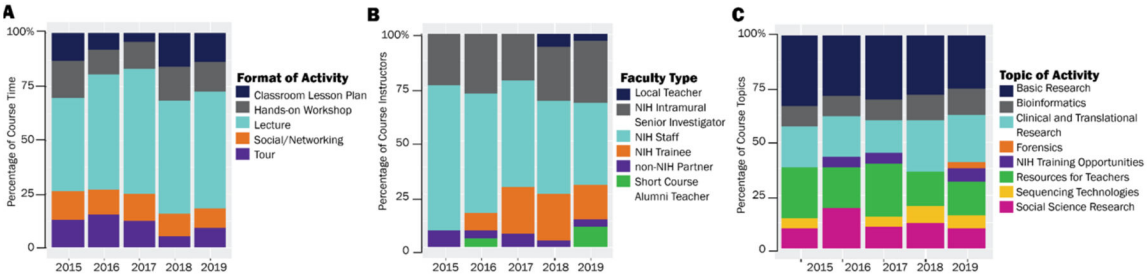

Figure 1: Configuration of Short Course.

A. Course format as allocated into five categories: classroom lesson plan, hands-on workshop, lecture, social/networking, and tour. Lectures make up the bulk of course time, but are interspersed with other activities for about 40-50% of total course time. B. Course faculty is allocated into six categories: local teacher, NIH intramural senior investigator, NIH staff, NIH trainee, non-NIH partner, and Short Course alumni teacher. NIH staff numbers remained fairly constant, but were increasingly supplemented with outside lecturers, trainees, and teacher volunteers. C. Course topics as allocated into eight categories : basic research, bioinformatics, clinical and translation research, forensics, NIH training opportunities, resources for teachers, sequencing technologies, and social science research.

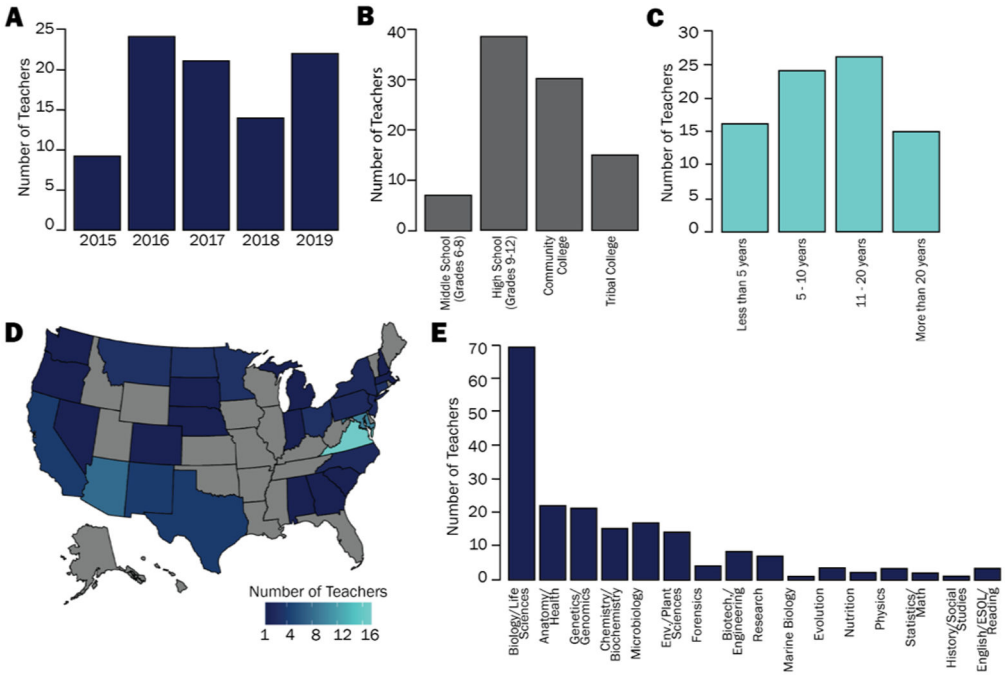

Figure 2: Characteristics of teachers attending the Short Course in Genomics.

A. Year of participation for 91 attendees from 2015-2019. B. Level of home institutions for 91 attendees from 2015-2019. C. Number of years of teaching experience for 91 attendees from 2015-2019. D. Map of 91 attendees from 2015-2019. States with the most attendees appear in lighter blue, while those with fewer attendees appear in darker blue. States with no attendees during these years appear in grey. E. Subjects taught by 81 attendees from 2016-2019.

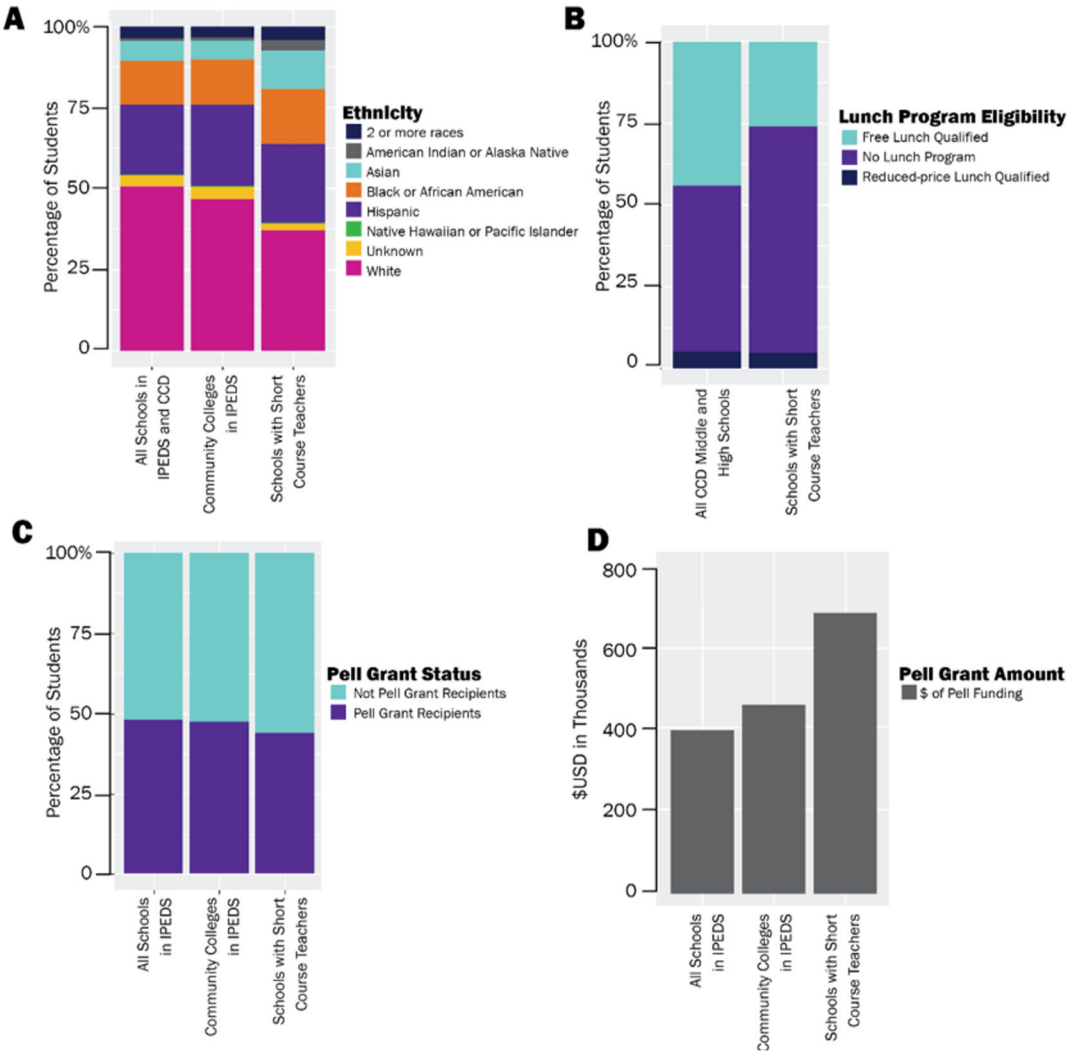

Figure 3: Characteristics of schools with participating Short Course educators from 2015-2019.

A. Ethnicity of students from selected schools, as indicated by colors in the legend at right. Schools with Short Course Teachers have more American Indian or Alaska Native Students, Black or African American students, and Hispanic students, than Community Colleges in the Integrated Postsecondary Education Data System (IPEDS) or all schools in IPEDS or the Common Core of Data (CCD) in general.

B. Lunch program eligibility of students from selected schools. Students from Short Course Schools were not more likely to be eligible for free or reduced-price lunches.

C. Number of Pell grants awarded from selected schools, as indicated by colors in the legend at right. Schools with Short Course teachers have similar numbers of Pell grant recipients as in all schools in IPEDS on average and all community colleges on average.

D. Amount of Pell grant awards from selected schools. Schools with Short Course teachers have a significantly higher Pell grant dollar amount awarded, as compared to all schools in IPEDS on average and all community college on average.

Table 1:
NHGRI Short Course in Genomics Application Review Criteria.

(2019) Applications are reviewed by a NHGRI employees from across subject areas at the institute, including management, education, and research personnel.

Criterion	Reasoning
1. Will the applicant benefit directly from attending the course?	We strive to assemble a cohort that has a good balance between younger and seasoned faculty. Younger faculty tend to have a more updated knowledge in genomics and less of a need for a refresher; the more seasoned participants may be more experienced in teaching, and in developing of new curriculum.
2. Did the applicant articulate a clear plan on how is he/she is going to use the materials taught in the course?	We favor teachers that will apply the information directly in their classrooms, versus administrators that plan to pass the resources to other faculty.
3. Is the course relevant to their curriculum?	We favor faculty who are designing new curriculum or introducing genomics for the first time in their science curriculum.
4. Will the teaching institution clearly benefit from the teacher participating in the course?	We favor teachers from institutions that will strongly benefit from the resources developed during the Course.

Table 2:

The Short Course in Genomics Framework.

This framework was developed using the Best Practices but could benefit from increased effort in the Areas for Growth.

Best Practices		Areas for Growth	
1	Wide institutional support	**1**	Increased travel subsidy awards for the under-resourced applicants
2	Bi-directional learning and benefits for attendee educators and lecturers	**2**	Dissemination and communication plan for outcomes and deliverables
3	Collaborative atmosphere and cohesive sense of community	**3**	Systematic evaluation for effectiveness and efficiency tracking
4	Emphasis is on serving the underserved and under resourced	**4**	Program scalability
5	Variety of course materials in both format and content		
6	Inclusion of diverse faculty		