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EDUCATION REPORT

Improved provider preparedness through an 8-part genetics and genomic education program

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ABSTRACT

Purpose: Large-scale genetics education appropriate for general practice providers is a growing priority. We describe the content and impact of a mandatory system-wide program implemented at Sanford Health.

Methods: The Imagenetics Initiative at Sanford Health developed a 2-year genetics education program with quarterly web-based modules that were mandatory for all physicians and advanced practice providers. Scores of 0 to 5 were calculated for each module on the basis of the number of objectives that the participants reported as fulfilled. In addition, the participants completed surveys before starting and after finishing the education program, which included a 7-item measure scored 7 to 28 on the perceived preparedness to practice genetics.

Results: Between 2252 and 2822 Sanford Health employees completed each of the 8 quarterly education modules. The ratings were highest for the module about using genomics to improve patient management (mean score = 4.3) and lowest for the module about different types of genetic tests and specialists. The mean perceived preparedness scores increased from 15.7 at pre-education to 19.1 at post-education ($P < .001$).

Conclusion: Web-based genetics education was highly effective in increasing health care providers' confidence about using genetics. Both comfort with personal knowledge and confidence regarding access to the system's genomic medicine experts increased significantly. The results demonstrate how scalable approaches can improve provider preparedness.

Introduction

The role of genetic testing in all aspects of medicine continues to increase rapidly,[1] but the number of genetic specialists is inadequate to meet current demands.[2] To realize the potential of genomic medicine, health care providers (HCPs) of all specialties, including those not trained in genetics, must be prepared to receive and act on genetic information.[3] Nongenetic HCPs, however, consistently report poor knowledge and low confidence about using genetic test results in the care of their patients, particularly for those in primary care.[4-9] Moreover, educational efforts often neglect the needs of HCPs such as nurses and advanced practice providers (APPs).[10,11] It is imperative for

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health systems to develop scalable strategies to engage, educate, and empower nongenetics HCPs in large numbers to use genetic information.[10,12,13]

Most studies about genomics education for nongenetic HCPs are encouraging, which show improvements in knowledge, self-efficacy, and attitudes of the HCPs.[14] Only a few of these data were derived from larger studies and over longer periods. Data from 143 general practitioners who completed a 2-year program showed substantial improvement in knowledge.[15] Similarly, a 1-year program that included 8 or more hours of teaching, supplemented by written materials, showed improved knowledge and attitudes toward genetic services in 121 primary care providers.[16] Pilot test data from a hybrid program of web-based modules and face-to-face lectures also showed improvements in knowledge.[17] Whether such improvements would be observed in larger, more sustained efforts that include nonvolunteers is unclear.

Here, we summarize a mandatory 2-year provider education program implemented at Sanford Health. We summarize feedback regarding how well the modules increased participants' self-reported knowledge, competence, and performance. We describe how effectively the modules met their stated objectives, and we identify factors that influenced ratings. The goal of this report is to offer guidance to health systems developing genetic education programs that are appropriate to the needs of providers who are not genetic specialists.

Materials and Methods

Overview

Sanford Health serves more than 2 million patients through more than 2500 HCPs. In 2014, Sanford Health launched the Imagenetics (internal medicine + genetics) Initiative to accelerate the integration of genetics into patient care system-wide.[18] A goal of the Imagenetics Initiative is to increase HCPs' preparedness to manage genetic findings, with an emphasis on the needs of general practice providers.

A multimodal education plan was launched in 2017. Between 2017 and 2019, the quarterly educational program that all physicians and APPs are required to complete included 8 novel computer-based training modules. The modules included a combination of text, case vignettes, embedded videos, infographics, and recorded lectures released quarterly. Medical residents and fellows were not required to complete the modules. The modules were also available to other Sanford Health HCPs and administrators. The overarching goals of the modules were to (1) increase awareness and baseline knowledge of genomic medicine, (2) increase comfort using genomic medicine in routine clinical care, and (3) increase the understanding of when and how to access genetics specialists within the Sanford Health System.

Development and administration of educational modules

Existing provider education programs were considered, but they could not be obtained and adapted to the needs of Sanford Health because of licensing restrictions. Thus, the module content was internally developed. The scope and sequence of learning objectives were established by an expert leadership panel of subject-matter experts, including medical geneticists, clinical pharmacists with training in pharmacogenomics (PGx), laboratory directors, and genetic counselors. The learning objectives were refined by smaller groups. The format of each web-based presentation was determined on the basis of the content and varied from voiceover lectures to interactive modules that provided access to external resources. The committees drafted content for approval from Imagenetics clinical leadership. Approved content was then sent to an internal learning, education, and development team for implementation. Content, including module-specific objectives, was also sent to the continuing medical education (CME) office for review, and providers could earn CME credits for completing each of 6 of 8 modules. Two modules addressing the genetics of drug response and genetic screening using the Sanford Chip were not granted CME credit. The CME-granting committee felt that because these modules focused on specific tests offered from the Sanford Medical Genetics Laboratory, they were not free of commercial bias and therefore did not qualify for CME credit.

The modules were distributed through an internal education portal that was used regularly for all mandatory provider educational programs and tracked the amount of time individuals spent on each module. Genetics education targeted to internists existed in the educational portal during the period of interest, although it was not promoted during the period of interest. The modules are available in the educational portal for providers to review as often as desired. Participation in each module was tied to compensation, with the providers being given 3 months to complete each successive module.

Content of modules

The content and objectives of each module are summarized in Table 1. The first series of 4 modules provided an overview of genomic medicine. The first module served as a foundation to help individuals better understand genomic medicine and how it can impact clinical practice. The content included how to recognize red flags for genetic disorders and an overview of how genes may affect responses to medications. The second module aimed to help individuals recognize genomic applications of precision medicine and the potential transformative effect on patient care. The components involved traditional applications, including analyses of the family histories of diseases. The module also addressed emerging applications such as genomic risk assessments for common diseases and provided an overview

Table 1 Content and objectives of individual modules

Module and Dates	Minutes to Complete, Median (IQR)	CME Credit	Overview	Learning Objectives
Series 1 (2017-2018): Genomic medicine in the clinical setting				
Module 1[a,b]: What is genomic medicine? Jul-Sept 2017	26 (38)	Yes	Foundational material to better understand genomic medicine and how it can impact clinical practice	• Describe genomic medicine • Interpret a pedigree • Differentiate between genotype and phenotype • Determine when to refer a patient for a genetic medicine consult • Describe PGx and its benefits
Module 2[b,c]: Current applications of genomic medicine Oct-Dec 2017	21 (29)	Yes	Descriptions of genomic applications of precision medicine, including preemptive genomic screening	• Recognize genomic applications of precision medicine • Classify the components of genomic medicine • Describe the Sanford Chip and its clinical utility • Recognize the strengths and limitations of preemptive precision medicine
Module 3[c,d]: The genetics of drug response Jan-Mar 2018	14 (20)	No	Clinical utility and application of PGx testing and the basics of drug metabolism	• Define PGx metabolizer types in the context of prodrug versus active drugs • Identify the scientific organizations that create the guidelines for clinical application of PGx • Recognize the components of the PGx test and utilize decision support tools • Order PGx testing and apply results
Module 4[c,d]: Different types of genetic tests and specialists Apr-Jun 2018	22 (33)	Yes	Examples of genetic variation and types of tests used to identify each, along with types of genetic specialists available to offer support	• Differentiate between somatic and germline variation • Summarize the different types of genetic testing • Recognize the clinical application for each type of genetic testing • Examine the clinical relevance of the genetic counseling process • Distinguish the difference between genetic professionals
Series 2 (2018-2019): Clinical applications of genomic medicine				
Module 5[e,f]: PGx in patient care Jul-Sept 2018	25 (30)	Yes	PGx principles review and common case examples showcasing available clinical decision support tools (recorded video lecture)	• Apply the principles of PGx to patient care • Recognize cases in which PGx testing is appropriate • Discuss the advantages and disadvantages of current approaches to PGx testing • Recognize the components of PGx reports and utilize decision support tools • Identify clinical resources related to PGx testing
Module 6[b,e]: The spectrum of genetic variants Oct-Dec 2018	16 (16)	Yes	Comparison of the genetics of mendelian and common diseases with an introduction to the identification and analysis of single-nucleotide variants (SNVs) (recorded video lecture)	• Summarize past efforts and current opportunities related to precision medicine • Outline the spectrum of genetic changes, or variants, between mendelian inheritance and common disease • Characterize SNVs • Appreciate the design and clinical utility of genome-wide association studies (GWAS) • Assess the clinical application of polygenic risk scores (PRS) to modify patients' clinical risk categories for more precise screening and treatment

(continued)

Table 1 Continued

Module and Dates	Minutes to Complete, Median (IQR)	CME Credit	Overview	Learning Objectives
Module 7[c,f]: Genetic screening and the Sanford Chip Jan-Mar 2019	8 (12)	No	High-level overview of Imagenetics with a focus on the return of results workflow for Sanford's precision prevention tool, the Sanford Chip	• Describe the three main initiatives of Sanford Imagenetics with an emphasis on the Sanford Chip • Delineate the Sanford Chip workflow for return of results • Apply Sanford Chip results to clinical practice through case examples
Module 8[c,f]: Using genomics to improve management Apr-Jun 2019	13 (15)	Yes	Case examples outlining how a genetic diagnosis improves patient outcomes and a brief description of Sanford's rare disease registry	• Describe how a genetic diagnosis can aid patient care • Evaluate cases in which referring a patient for a genetic medicine consult may be valuable • Apply PGx testing results to medical management • Discuss the value that the Coordination of Rare Diseases at Sanford (CoRDS) provides to patients, families, and researchers

Apr, April; *CME*, continuing medical education; *IQR*, interquartile range; *Jan*, January; *Jul*, July; *Jun*, June; *Mar*, March; *Oct*, October; *PGx*, pharmacogenomics; *Sept*, September.

[a]Combination of recorded lecture and interactive format.

[b]Genetic principles content.

[c]Recorded lecture format.

[d]Combination of general principles and "how-to" content.

[e]Interactive format.

[f]"How-to" content.

of the Sanford Chip Program. The third module focused on PGx and drug metabolism in the context of prodrug vs active drug. The content included where to find the guidelines for PGx testing and the use of clinical decision support tools. In the final module of the first year, the participants learned the difference between somatic and germline genetic testing. Various types of genetic testing options and their clinical applications were addressed, as were the roles of genetics professionals such as genetic counselors.

The second series of 4 educational modules addressed more specific clinical applications. The first module of the second year focused primarily on the clinical application of PGx testing. Through a recorded lecture format, the participants learned when to order PGx testing and the pros and cons of current approaches. The module also reviewed components of a PGx report and expanded on how to utilize available decision support resources. The second module was also a recorded lecture and addressed the association between different types of genetic variants, mendelian inheritance, and common disease. The module also provided details about single-nucleotide variants, how they are identified, and how they may be used to estimate the polygenic risk for common diseases. The third module addressed the Sanford Chip Program, an elective genetic test that provides preemptive PGx testing and screens individuals for medically actionable genetic predispositions. Using case studies, the module provided examples of the application of the Sanford Chip to patient care as well as workflow for the return of results to providers and patients. The final module explained how a genetic diagnosis could improve patient care in a series of case studies. The content reviewed how to identify situations where a consult with a genetic specialist is warranted and how PGx findings could influence medical management. The module concluded with a discussion of the rare disease registry at Sanford Health.

Measures of effectiveness

Outcome data were analyzed from all available anonymous surveys administered to educational program participants via SurveyMonkey (Momentive, Inc.) for quality improvement purposes. Perceptions about preparedness, access to genetic specialists, and utility were queried rather than more objective measures, such as genetic knowledge scales, to minimize participant burden and because the content of year 2 modules had not been finalized at the time the program was launched.

Assessments of individual modules

After the completion of each of the 8 educational modules, the participants provided yes or no responses to the following statements: (1) "The content of this activity matched my current (or potential) scope of practice;" (2) "This activity increased my knowledge (knowing what to do);" (3) "This activity increased my competence (knowing how to do something);" and (4) "This activity improved my performance (ones actual behavior in practice)." All

modules except the last also include a fifth statement, "Were your personal objectives successfully achieved?"

Pre- and post-education assessment

Before starting the first educational module and after completing the final one, surveys included the measures mentioned in the later sections.

Perceived preparedness

The individuals were asked to rate how prepared they felt about genetics in medicine in a set of 7 items: (1) I feel well-informed about knowledge of genetics; (2) I feel well-informed about genetic testing in general; (3) I feel comfortable ordering a genetic test to genetic conditions in my specialty; (4) I feel comfortable ordering a genetic test for disease susceptibility (eg, *BRCA1/BRCA2* testing for the risk of breast and ovarian cancer); (5) I feel comfortable ordering a pharmacogenetic test to predict risk of adverse events or likelihood of response (eg, *CYP2C9/VKORC1* and warfarin therapy); (6) I have access to genetics expertise when I have a question related to a patient; and (7) I feel that my medical training adequately prepared me to appropriately order and use genetics tests. The response options of "strongly disagree," "disagree," "agree," and "strongly agree" were scored 1 to 4, respectively, and summed to create a summary score of 7 to 28, with higher scores indicating stronger feelings of perceived preparedness. The scale items were novel but demonstrated strong internal consistency (Cronbach alpha of 0.91 at pre-education and 0.93 at post-education).

Perceived access to genetic specialists

Individuals were asked separate yes or no questions about whether they had a geneticist or genetic counselor to whom they could refer patients.

Perceived utility

Individuals were also asked how useful they thought pharmacogenetic results would be for managing their patients' health, with response options of "very useful," "somewhat useful," "not very useful," and "not at all useful."

Open-ended items

The respondents provided open-ended feedback to the following 2 questions on both pre- and post-education questionnaires: "How do you feel about genetic testing becoming part of routine clinical care?" and "What additional information would be helpful to increase your comfort with using genetics in clinical care?"

Respondent characteristics

Respondents self-reported their gender; their age in 10-year increments; role (Physician, APP, Nursing, Pharmacy, other); specialty; and, if applicable, years out of residency, training (US or non-US medical school), and residency training setting (university-based, hospital-based, other).

Data analysis

The analyses of pre- and post-education surveys were limited to data from physicians and APPs because these providers were the target audience and were required to complete the modules. Module-specific ratings included all survey completers because physicians and APPs could not be distinguished from individuals with other roles. To avoid instances where outcomes were provided long after the completion of education modules, data were analyzed from surveys we could match to records confirming module completion within 14 days. We also omitted 462 respondents from analyses for pre-education surveys who reported that they had already completed the required Sanford training modules.

Chi-square and Wilcoxon rank sum tests were used to compare the characteristics of the respondents of the pre- and post-education assessments. Linear and logistic regression models were used to compare pre- and post-education survey data as appropriate to the distributions of responses. Covariates included gender, age, and role. Generalized linear models with logit links and binomial distributions were also used to compare module-specific evaluation data by topic, although no respondent characteristics were included in these statistical models because the surveys were anonymous. We also analyzed module-specific education descriptively by content and format. The content of individual modules was classified using the frameworks proposed for genetic literacy[19,20] as primarily principles knowledge (underlying theoretical principles of genetics and medical genetics), "how-to" knowledge (practical knowledge concerning the proper use of genetic testing), or both. The format of the individual modules was classified as interactive, recorded presentation, or both.

Open-ended data were classified using approaches developed for coding qualitative data.[21] First, 1 study team member (K.D.C.) proposed an initial codebook based on the review of responses. Two study team members (L.N.G. and C.L.P.) then coded each response set independently. In instances where interrater reliability metrics were suboptimal, the codebooks were revised, and data were recoded until agreement was strong (Cohen $\kappa > 0.8$). The final differences in coding were reconciled by a single study team member (L.N.G.).

Available-case analyses were conducted using R version 4.0.3 (R Foundation for Statistical Computing). The study was deemed exempt from human subjects research by the Sanford Research Institutional Review Board.

Results

Response rates and provider characteristics

Between 2252 and 2822 individuals completed each module, and between 1263 and 2377 individuals completed each postmodule assessment (Supplemental Table 1 and Supplemental Table 2). The average response rates to

module-specific surveys decreased from 95.3% after completion of the first module to 50.9% after completion of the final module. The median time required to complete each module ranged from 8 to 26 minutes (Table 1), with participants spending an average of 221 minutes (SD = 151 minutes) overall.

Pre- and post-education assessments had comparable completion percentages from physicians and APPs. At pre-education, 1719 of 2102 physicians and APPs (81.8%) completed the pre-education survey, and 1263 of 2482 physicians and APPs (50.9%) completed the post-education survey. The characteristics of physicians and APPs who completed the pre-education and post-education surveys are summarized in Table 2. The respondents analyzed from the post-education survey were more likely to be APPs (38.8% vs 43.1%, respectively, $P = .019$), were older (58.2% over the age of 40 vs 65.1%, respectively, $P < .001$), and were more likely to report receiving genetics education in medical school or during residency (52.4% vs 64.1%, respectively, $P < .001$) than respondents of the pre-education survey. The physicians who completed the post-education survey tended to be more experienced (51.7% at least 10 years out of residency vs 64.9%, respectively, $P < .001$) than the physicians who completed the pre-education survey.

Table 2 Characteristics of pre-education and post-education survey respondents

Characteristic	Pre-Education Survey, *n* (%)	Post-education Survey, *n* (%)	*P*
Role			.019
Physician	1052 (61.2)	719 (56.9)	
APP	667 (38.8)	544 (43.1)	
Age, y			<.001
<30	97 (5.6)	54 (4.3)	
30-39	618 (36.0)	385 (30.5)	
40-49	428 (24.9)	343 (27.2)	
50-59	304 (17.7)	254 (20.1)	
60-69	225 (13.1)	197 (15.6)	
70+	38 (2.2)	24 (1.9)	
Missing age	9 (0.5)	6 (0.5)	
Primary specialty[a]			
Family medicine	383 (22.3)	274 (21.7)	
Internal medicine	137 (8.0)	90 (7.1)	
OB/Gyn	76 (4.4)	43 (3.4)	
Pediatrics/Pediatric subspecialties	156 (9.1)	99 (7.8)	
Years out of residency[b]			<.001
<5	289 (27.5)	113 (15.7)	
5-9	208 (19.8)	130 (18.1)	
10-14	136 (12.9)	99 (13.8)	
15-19	131 (12.5)	87 (12.1)	
20+	266 (25.3)	263 (36.6)	
Out of residency missing	22 (2.1)	27 (3.8)	
Genetics education in medical school or residency	900 (52.4)	810 (64.1)	<.001

Evaluations of specific modules did not collect information about respondent characteristics.

APP, advanced practice provider; *OB/Gyn*, obstetrics/gynecology.

[a]At pre-education, respondents could endorse multiple primary specialties and write in others. At post-education, respondents could choose a single response option and write in others. Additional specialties reported are summarized in Supplemental Table 2.

[b]Data for these items were collected only from physicians.

Postmodule assessments

Most individuals who completed assessments judged the modules' formats to be satisfactory. Between 77.1% and 92.6% of respondents reported that the format of each module was appropriate, and when queried in year 2, over 96% of participants said that the length of each module was appropriate (Supplemental Table 3). When improvements to the format of modules were suggested, the respondents asked for case-based presentations more often than other changes.

Assessments of whether individual modules met goals are summarized in Table 3. The percentages of respondents who reported that the modules increased their knowledge increased their competence, and improved their performance were lowest for the modules that addressed different types of genetic tests and specialists and current applications of genomic medicine. In contrast, the percentages of respondents who reported that the same module goals (knowledge, competence, performance) were achieved were highest for the modules about using genomics to improve management, the module about genetic screening and the Sanford Chip, and the module about PGx in patient care.

Analyses suggested that the respondents preferred modules that focused on practical, "how-to" knowledge. For the 3 modules where the content was primarily "how-to" knowledge, 92.9% of respondents reported increased knowledge, 87.4% reported increased competence, and 73.6% reported improved performance (Supplemental Table 4). In contrast, across the other 5 modules, 87.5% reported increased knowledge, 76.7% reported increased competence, and 62.3 reported improved performance (all $P < .001$). Interestingly, analyses showed little difference in the respondents' ratings of modules that primarily used either an interactive or a recorded format (Supplemental Table 5).

Pre- and post-education assessments

The mean scores on our 7 to 28 scale of perceived preparedness increased from 15.7 at pre-education to 19.2 at post-education (difference (diff) = 3.5, 95% confidence interval [CI] = 3.2-3.8, $P < .001$). Regression analyses are summarized in Table 4. Changes were particularly large among APPs, where the mean scores increased from 14.2 to 18.8 (diff = 4.6, 95% CI = 4.1-5.1, $P < .001$). In contrast, the mean scores among physicians increased from 16.7 to 19.4 (diff = 2.7, 95% CI = 2.3-3.1, $P < .001$). Perceived preparedness scores varied by age across time points, with

Table 3 Percentage of respondents who reported that educational modules achieved goals

Module	Increased Knowledge, %	Increased Competence, %	Improved Performance, %	Matched Scope of Practice, %	Personal Objectives Met, %
1. What is genomic medicine? (n = 1914-2043)	86.5	76.1	63.6	88.1	91.8
2. Current applications of genomic medicine (n = 1687-1960)	87.3	76.4	60.9	83.1	86.1
3. The genetics of drug response (n = 1635-2049)	90.3	82.1	65.7	85.0	89.6
4. Different types of genetic tests and specialists (n = 1224-1292)	84.1	71.5	54.7	74.7	79.9
5. PGx in patient care (n = 1471-1699)	93.0	87.9	73.4	79.7	87.0
6. The spectrum of genetic variants (n = 1445-1643)	89.1	76.4	65.5	74.1	88.1
7. Genetic screening and the Sanford Chip (n = 2063-2370)	92.5	87.5	73.2	79.4	90.5
8. Using genomics to improve management (n = 1211-1233)	93.3	86.9	74.3	80.8	[a]

PGx, pharmacogenomics.
[a]Item was not included in the module-specific survey.

an average decrease of 0.3 points on the scale per 10-year increase in age (95% CI = –0.4 to –0.2, $P < .001$). We also observed lower scores at both time points among older respondents.

Increases on all items of the perceived preparedness scale were observed from pre-education to post-education (Figure 1). The largest increases were observed on the percentage of participants who reported feeling well-informed about their knowledge of genetics (36% agreed at pre-education vs 81% agreed at post-education) and the percentage of participants who reported feeling comfortable ordering PGx testing (19% agreed at pre-education vs 60% agreed at post-education). At pre-education, the respondents were least likely to report feeling comfortable ordering PGx testing (19% agreed), whereas at post-education, the respondents were least likely to report that their medical training adequately prepared them to order and use genetic tests (55% agreed). At both time points, the respondents were most likely to report that they had access to genetics expertise when they had questions about a patient (59% agreed at pre-education, 86% agreed at post-education).

We also observed an increase in the proportion of physicians and APPs who reported having access to a geneticist or genetic counselor to whom they could refer patients when asked as a yes or no question. In total, 64.9% of physicians and APPs reported access to one or both of these specialists at pre-education compared with 82.7% at post-education (P <.001). Increases were also observed in the perceived utility of PGx testing. At pre-education, 22.2% of respondents reported that PGx results would be "very useful" for managing their patients' health, compared with 37.8% of respondents at post-education ($P < .001$).

Analyses of open-ended items also showed a lower likelihood of addressing further education as helpful in the post-education survey than in the pre-education survey. The odds that the respondents' written responses about what would increase their comfort with genetics-addressed education decreased by 45.6% after education than before education ($P = .003$). Interestingly, the odds that the respondents' written responses were about the need for more experience or practice were 4.95 times higher at post-education than at pre-education ($P < .001$).

Discussion

The Sanford Health experience is one of the first examples of a sustained, mandatory genetics education program at a major health system. Over 2000 providers completed the program over a 2-year period, and the program yielded

Table 4 Summary of linear regression analyses of perceived preparedness scores (7-28 scale)

Variable	Estimate	Standard Error	P
Intercept	17.44	0.39	<.001
Male gender (ref: female)	–0.26	0.18	.156
Age in y (ref: <30)			<.001
30-39	–0.28	0.37	
40-49	–0.64	0.38	
50-59	–0.98	0.39	
60-69	–1.15	0.41	
70+	–0.52	0.64	
APP role (ref: physician)	–2.50	0.23	<.001
Change among physicians, post-education minus pre-education	2.67	0.20	<.001
Change among APPs, post-education minus pre-education	1.96	0.32	<.001

Model estimates represent the difference in scale scores compared with the reference group.
APP, advanced practice provider; *ref*, reference.

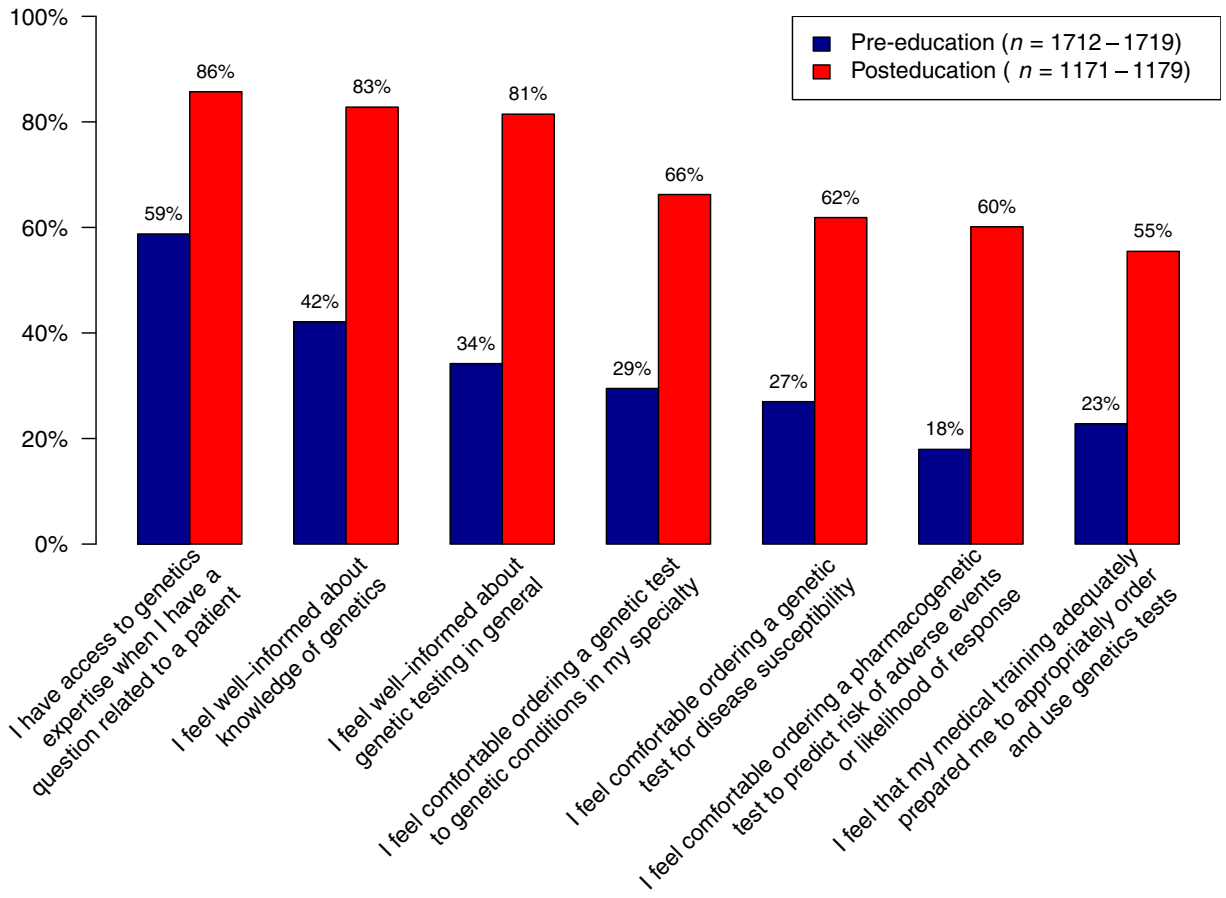

Figure 1 Percentage of physicians and advanced practice providers who agreed or strongly agreed with each item of the perceived preparedness scale. Percentages were estimated using logistic regression equations, with adjustment for role, age, and gender.

significant improvement in provider preparedness, including large increases in provider confidence, awareness of help, and perceived utility of genetic testing. A large majority of individuals reported that the modules increased their knowledge and competence and that their personal objectives were met. The findings from this program demonstrate how committed health systems can effectively provide genetics education to their HCPs as part of a comprehensive plan to implement genomic medicine.

Importantly, whereas substantial investment was necessary to create the educational modules, program completion did not appear to be a burden. Well over 90% of individuals reported that the length of each of the modules was appropriate when that question was included in module assessments. Efforts to educate providers about genetics have varied greatly in their time demands, ranging from half-day courses to multiday seminars to monthly meetings over a year.[22-26] Such efforts are often difficult for providers to accommodate in their schedules. Organizations such as the Jackson Laboratory, the Centers for Disease Control and Prevention, and the International Society of Nurses in Genetics have developed and curated web-based provider education programs that provide greater scheduling flexibility.[27-29] The Sanford Health program has taken these efforts a step further by providing web-based programs that individuals can complete at their own pace, but have been tailored to the services and health care provider support infrastructure developed by Sanford's Imagenetics Initiative.

One of the key goals of Sanford's genomics educational program was to make providers who may have little experience with genetics more comfortable with population preemptive genetic screening. The modules focused on the use of genetic information in the care of both healthy and sick patients as well as the benefits and limitations of genetic testing. The percentage of individuals who reported that the modules increased their competence and performance was more than 10% higher when the modules emphasized "how-to" knowledge or case examples rather than genetic principles. In particular, the module about genetic screening and the Sanford Chip was among the highest-rated even though it did not qualify for CME credit. The findings from our work add weight to calls for a greater use of theoretical frameworks and educational theory to inform program development by demonstrating how content may affect responses to genetic education programs.[14,30-32] Although it is important to include principles knowledge, doing so in a manner that also includes "how-to" content may yield the best

results, especially if it is linked to a high-profile program that could affect the practice of most participants.[19,20]

One factor that may have increased the effectiveness of the genetics education program was a significant effort to increase provider support for and awareness of the role for genetics in medicine before the launch of the formal educational program. Experts generally agree that education alone may be insufficient to ensure the appropriate use of genetic testing.[33,34] The efforts at Sanford Health included infrastructure development for the integration of genetic information into the electronic medical record (EMR) and development of automated clinical decision support that would provide point-of-care guidance to providers. The educational modules that addressed "how-to" content leveraged the content of the existing infrastructure. In a parallel effort, Sanford Health increased the number of genetic counselors in its system and embedded them in all internal medicine clinics. The combination of the "human" resource with support in the EMR may have enhanced educational efforts by making providers more aware that help for responding to genetic information was readily available.[35,36]

Notably, the genetic education program overlapped with the launch of the Sanford Chip in 2018, which is a flagship genetic testing program in primary care settings that offers pharmacogenomic testing and optional genetic risk information. Efforts to make providers and patients aware of this new elective service likely had a significant impact on provider awareness for the role of genetics in medicine and increased the salience of the genetics education program and engagement with the content. Importantly, other studies suggest that the providers may be unwilling to engage with genetic information if they feel inadequately prepared or supported.[37-39] The development of an environment to manage genetic information and the launch of provider education in genetics before offering the Sanford Chip may be a reason that over 11,000 patients have participated in the program to date.

One limitation of our study was the use of self-assessments of genomic readiness. Preliminary analyses of data from 2018 showed that the providers altered medication choices or patient monitoring in 45% of encounters where potential drug-gene interactions were identified, including in 59% of encounters involving clopidogrel. These rates are higher than those observed in related clinical trials[40] and much higher than a 10% concordance rate with clinical decision support recommendations observed at Sanford Health overall. Future work will refine these analyses as well as examine more objective measures of provider knowledge and behavior. Limitations also include the analysis of anonymous data that did not allow comparisons of pre- and post-education responses for specific individuals. It is possible that individuals with more positive attitudes about genomics were more likely to complete the post-education survey. The program was implemented in a single health care system, and the results may not generalize well to others, particularly systems lacking the bioinformatics infrastructure and clinical decision support to complement the education.

Despite the significant efforts described here, our analyses still suggest that the providers felt additional education would be helpful. This, along with the perception that genetics has promise for the future, demonstrates the need to supplement system-wide educational efforts. Additional programs that Sanford Health has implemented include developing brief educational PowerPoint presentations that are available on demand. These presentations address topics such as the meaning of uninformative findings and how to use Genomic Indicators, which are tools in the Epic EMR system that document genomic findings as discrete fields that can trigger automated decision support.

Nevertheless, our work demonstrates that health systems can effectively deliver provider-directed genetic education at scale. The modules summarized here have been combined into a single module, which is updated as needed to ensure that content is current with evolving best practice recommendations. All new physicians and APP hires complete this single module during orientation. We intend to provide ongoing education to build upon this existing foundation and respond to the rapid speed at which genetics is impacting medicine.

Data Availability

Data and code will be made available on request. Inquiries can be directed to the corresponding author.

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Ethics Declaration

The study was deemed exempt from human subjects research by the Sanford Research Institutional Review Board.

Conflict of Interest

Robert C. Green has received compensation for advising the following companies: AIA, Grail, Humanity, Kneed Media, Plumcare, UnitedHealth, Verily, Vibrent Health, and Wamberg and is the cofounder of Genome Medical, Inc, a technology and services company providing genetics expertise to patients, providers, employers, and care systems.

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Additional Information

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Supplementary Table 1. Completion rates of each survey.

Survey	Completed Survey and Analyzed	Number who Completed Each Module	Completion Rate
Pre-education [a]	1,719	2,102	81.8%
Module 1	2,153	2,252	95.6%
Module 2	2,014	2,275	88.5%
Module 3	2,196	2,509	87.5%
Module 4	1,639	2,308	71.0%
Module 5	1,890	2,822	67.0%
Module 6	1,654	2,514	65.8%
Module 7	2,379	2,534	93.9%
Module 8	1,592	2,553	62.4%
Post-education[a]	1,263	2,482	50.9%

[a] Analyses of pre-education and post-education surveys were restricted to physicians and advanced practice providers.

Supplementary Table 2. All primary specialties reported in pre-education and post-education surveys.

Primary Specialty [a]	Pre-education n (%)	Post-education n (%)
Allergy/Asthma	6 (0.3%)	4 (0.3%)
Anesthesiology [b]	107 (6.2%)	27 (2.1%)
Cardiology	40 (2.3%)	36 (2.9%)
Dermatology	21 (1.2%)	12 (1.0%)
Ear, Nose & Throat	23 (1.3%)	13 (1.0%)
Emergency Medicine [b]	39 (2.3%)	38 (3.0%)
Endocrinology	15 (0.9%)	14 (1.1%)
Family Medicine	383 (22.3%)	274 (21.7%)
Gastroenterology	30 (1.7%)	16 (1.3%)
General Surgery	64 (3.7%)	41 (3.2%)
Specialty Surgery	29 (1.7%)	27 (2.1%)
Infectious Disease	11 (0.6%)	13 (1.0%)
Internal Medicine	137 (8.0%)	90 (7.1%)
Medical Geneticist/Counselor	19 (1.1%)	9 (0.7%)
Nephrology	24 (1.4%)	9 (0.7%)
Neurology	50 (2.9%)	20 (1.6%)
OB/Gyn	76 (4.4%)	43 (3.4%)
Oncology	57 (3.3%)	29 (2.3%)
Ophthalmology	9 (0.5%)	7 (0.6%)
Orthopedics	87 (5.1%)	45 (3.6%)
Pediatrics/Pediatric Sub-Specialties	156 (9.1%)	99 (7.8%)
Physical Medicine & Rehabilitation	12 (0.7%)	8 (0.6%)
Psychiatry/Behavioral Health	38 (2.2%)	32 (2.5%)
Pulmonology	21 (1.2%)	19 (1.5%)
Radiology	47 (2.7%)	48 (3.8%)
Urology	45 (2.6%)	24 (1.9%)

[a] At pre-education, respondents could endorse multiple primary specialties and write in others. At post-education, respondents could choose a single response option and write in others.

[b] These specialties were not included as standard response options and were written in by respondents.

Supplementary Table 3. Participants' ratings of the length and format of educational modules.

Module	Length of module was appropriate	Format was appropriate; no changes needed
1: What is genomic medicine? (n=1914-2043)	[a]	88.7%
2: Current applications of genomic medicine (n=1687-1960)	[a]	84.2%
3: The genetics of drug response (n=1635-2049)	[a]	85.3%
4: Different types of genetic tests and specialists (n=1224-1292)	[a]	77.1%
5: PGx in patient care (n=1471-1699)	96.1%	81.0%
6: The spectrum of genetic variants (n=1445-1643)	97.7%	82.1%
7: Genetic screening and the Sanford Chip (n=2063-2370)	98.6%	88.7%
8: Using genomics to improve management (n=1211-1233)	98.9%	92.6%

[a] Item was not included in the module assessment.

Supplementary Table 4. Percent of respondents who reported that modules met objectives, by content

Objective	Only How-to	Only Principles	Both
Increased knowledge	92.9%	87.5%	87.6%
Increased competence	87.4%	76.3%	77.5%
Improved performance	73.6%	63.2%	60.9%
Matched scope of practice	79.9%	82.5%	80.5%
Personal objectives met	88.9%	88.8%	85.5%

Supplementary Table 5. Percent of respondents who reported that modules met objectives, by format

Objective	Only Interactive	Only Recorded	Both [a]
Increased knowledge	89.7%	91.1%	86.5%
Increased competence	81.3%	82.4%	76.1%
Improved performance	66.2%	69.7%	63.6%
Matched scope of practice	80.8%	77.0%	88.1%
Personal objectives met	87.1%	87.5%	91.8%

[a] Only the first module about “what is genetic medicine?” used both formats.