# Biotech 101: An Educational Outreach Program in Genetics and Biotechnology.

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## Abstract:

Recent advances in research and biotechnology are making genetics and genomics increasingly relevant to the lives and health of the general public. For the public to make informed healthcare and public policy decisions relating to genetic information, there is a need for increased genetic literacy. Biotech 101 is a free, short-course for the local community introducing participants to topics in genetics, genomics, and biotechnology, created at the HudsonAlpha Institute for Biotechnology. This study evaluated the effectiveness of Biotech 101 in increasing the genetic literacy of program participants through pre-and-post surveys. Genetic literacy was measured through increases in self-perceived knowledge for each content area covered through the course and the self-reported impact the course had on various aspects of participants' lives. Three hundred ninety-two individuals attended Biotech 101 during the first three course offerings. Participants reported a significant increase in self-perceived knowledge for each content area ($p < 0.01$). Participants also reported the program had high levels of impact on their lives and decision-making, a high likelihood for continued self-learning, and overwhelming satisfaction with course content and logistics. Biotech 101 is an effective mechanism for impacting participants' lives and genetic literacy and serves as a model for other similar programs, adding to the currently limited evidence base regarding public educational strategies in genetics and biotechnology.

**Keywords:** ethics | clinical psychology | public health | human genetics | genetic counseling | genetics education | public education | biotechnology

## Article:

Introduction

Advances in genetic research and technology are giving genetics an increasing presence in medicine, the media, popular culture, and everyday conversation (Lamb et al. 2009; McInherney

2008; Varmus 2002). However, exposure to a topic does not necessarily equal understanding (Lanie et al. 2004). There is a growing need for the public to understand the basic principles behind genetics and genomics, how these topics can affect their lives and the corresponding ethical, legal and social issues (Clayton 2003; Lanie et al. 2004). This understanding will increase the public's genetic literacy, allowing for more informed healthcare consumers who are able to think critically about genetic issues confronted in the media, in popular culture, and at the doctor's office.

Genetic literacy has been defined as possessing the requisite knowledge and skills to "manage uncertainty and to participate as a full partner in a prevention-based healthcare system that is increasingly informed by genetic perspectives" (McInerney 2002, p. 372). This requisite knowledge and skills is not static over time: as genetic research and society issues change, so does the knowledge needed to think critically about these topics. In that regard, genetically literate individuals must have a toolset for continued self-learning.

Several recent studies have revealed numerous misconceptions and low levels of genetic literacy among the American public, from high school essay writers to senior citizens (Bates et al. 2003; Frazier et al. 2006; Kessler et al. 2007; Lanie et al. 2004; Morris et al. 2003; Shaw et al. 2008). For many adult Americans a number of years have passed since their last course in science, much less genetics. With the current pace of genetic discovery, we cannot expect the information taught in the high school or college classrooms of the past to be sufficient for life-long genetic literacy. There is a need for genetic education programs aimed at increasing and updating genetic knowledge among adults in the local community. One model is for those directly involved in research and industry to be actively involved in public outreach and education (Friedman 2008; Munn et al. 1999).

Biotech 101 is a short course in genetics and biotechnology for the local public, created by the HudsonAlpha Institute for Biotechnology (HA) in Huntsville, Alabama. The course is sponsored by both HudsonAlpha and a community partner (Servis1st Bank), allowing it to be offered at no cost to participants. The goals of Biotech 101 are to help the public better understand the basics of genetics, genomics, and biotechnology, and to help them connect these basic science concepts to applications in research and healthcare. The course is conducted with no bias or solicitation and does not endorse specific tests or therapeutics. The course is held on five consecutive Tuesday evenings, taught by institute faculty members. Each week, participants are introduced to a different topic relating to genetics and biotechnology: an introduction to DNA, genetics and genomics, human variation and disease, cancer and immunology. The course also introduces examples of real-world biotechnology applications. The first Biotech 101 course was taught in the fall 2008 followed by the second and third offerings in the spring and fall 2009, respectively. Biotech 101 is an example of a focused effort, put forth by an institution involved in research and industry, aimed to increase the public's genetic literacy.

While there are many education programs throughout the country, there has been little formal evaluation of these programs (Dolan et al. 2004; Metcalfe et al. 2008). It is important for a program to evaluate its effectiveness, to guide program modifications and inform future program development (Metcalfe et al. 2008). In response to the need for evidence-based educational programming, this study presents the evaluation of Biotech 101 with the goal of determining the impact of the program on participant genetic literacy.

## Methods

### Course Content

The Biotech 101 course is held on five consecutive Tuesday evenings. The first class session focuses on an introduction to DNA, genetics, and biotechnology. The class covers the relationship among DNA, genes, chromosomes and genomes and discusses how DNA contributes to traits and disease. The second class focuses on the different types of genetic variation including chromosome changes, gene mutations, and single nucleotide polymorphisms (SNPs). Additional attention is given to the use of variation for identification, ancestry, and determining disease risk and treatment options. Cancer genetics and genomics is presented during the third week. In this class, cancer as a genetic disease, but most often not an inherited disease is addressed. Current research efforts in cancer genomics and recent advances in targeted therapeutics are also discussed.

The fourth class focuses on DNA sequence variation at a population level including new discoveries in human health based on comparative genomics and diverse human populations. The fifth and final class centers on immunology and the role of the human immune system, antibiotics and vaccines in fighting and preventing infection. A discussion of how researching bacterial and viral genomes can aid in the development of diagnostic tools and treatments is included. Throughout the course, speakers highlight genomic discoveries that have been made by HudsonAlpha faculty and associate companies. Please refer to electronic supplementary material (ESM Figure 1) for additional information about the course structure, content and instructors. For more specific information about Biotech 101, contact the authors.

### Participants

There were three course offerings of Biotech 101 during the study timeframe: fall 2008, spring 2009, and fall 2009. The course is advertised through a variety of means, including newspaper, radio, emails, and information on the HudsonAlpha website. Online registration remained open until the maximum number of participants was reached, with each course filling to capacity

quickly. There were 110 participants in the fall 2008 class, 86 in the spring 2009 class, and 196 in the fall 2009 class (392 in total). The first two course offerings were held in an auditorium at HudsonAlpha, with a capacity of approximately 90 people. Beginning with the fall 2009 offering, the course was moved to the Jackson Center, a nearby conference center on the Biotech Campus, that could accommodate a larger audience. The program "no-show" rate is low. We expect that approximately 10–15% of those who register for the course will fail to attend, due to a variety of reasons including illness and schedule conflicts. Program participants were all members of the greater Huntsville community, which has an estimated population of 319,510 (U.S. Census Bureau 2009), and represented a variety of ages, occupations, ethnicities, and education levels. Since the study, an additional 372 people have completed Biotech 101. To date, 764 people (0.24% of the Huntsville population) have been reached through Biotech 101.

Instrument

The study employed a mixed methods approach combining both quantitative and qualitative research collected through a pre-test/posttest study design. The pre- and post survey instruments were designed specifically for Biotech 101 and were not modeled from nor included any other known standardized questions. Although there was no formal piloting of the survey instruments or reliability testing conducted on either survey, both surveys were reviewed carefully by HudsonAlpha staff for readability and clarity. Additionally, one question was removed entirely from analysis because it was clear upon answer examination that participants were unable to answer the question as intended. The simple survey design includes standard likert scale, multiple choice and short response questions. Standard survey design techniques including clear question stem formation, unambiguous answer options and attention to question fatigue were used throughout the creation of the instruments.

Program participants were provided an introductory letter, informing the participants that survey completion was voluntary and anonymous. By completing the surveys, course participants agreed to participate in the study. Of the 392 total participants, a total of 341 pre-tests and 282 posttests were returned, a response rate of 87% and 72% respectively. Pre-tests and posttests were completed by participants on-site and returned at the conclusion of the first and last Biotech 101 sessions. The HudsonAlpha Institutional Review Board (IRB) reviewed and approved this project.

Both the pre-test and the posttest assessed demographic data and self-perceived knowledge for 11 scientific topics covered through the course, including the difference between genetics and genomics, the relationship between genetics and the environment, and the relationship between biotechnology and modern medicine. Multiple related topics were covered during each class session. In addition, the pre-test assessed the participants' reason for attending and expectations for the course. The posttest included additional questions about the impact of Biotech 101 on the

participants' lives, satisfaction with program logistics, and the likelihood of continued learning. The posttest also included two open-ended questions: "What can be done to improve the course?" and "Please provide any additional comments about HudsonAlpha's Biotech 101." These questions allowed participants to bring up issues and opinions that were important to them that might not have been addressed previously on the survey. The pre-test and posttest surveys can be found as electronic supplementary material (ESM Figure 2 and ESM Figure 3).

## Analysis

Quantitative statistical analysis was performed using Statistical Package for the Social Sciences (version 16.0, SPSS Inc, Chicago, Illinois). Graphs were created using Microsoft Excel. Descriptive statistics were performed to identify participant characteristics and determine the most appropriate statistical analyses to measure program impact. Cases with missing values were excluded from analysis only if the missing value was needed for the particular statistical measure.

A pre-test and posttest aggregate perceived knowledge score (postscore) was calculated overall, and for each participant, by summing the perceived knowledge level reported for each of the individual topic areas ("not confident at all = 1," "extremely confident" = 5). These data represent a wide range of possible scores (11–55), allowing the variable to be treated as continuous. Mann–Whitney U tests were conducted to assess the difference in the median level of perceived knowledge between the pre-test and the posttest and used for each individual topic area as well. Spearman's rho correlation coefficient was used to investigate the relationship between total postscore and categorical variables such as level of impact on the participants' lives and likelihood of continued learning.

Qualitative data analysis was based in Grounded Theory (Glaser and Strauss 1967) and used the constant comparative method (Glaser 1965) to elucidate themes. Two independent coders (KME and NPC) categorized open-ended responses by theme. The coders were in complete agreement for 80.7% of the 357 total qualitative responses, and partial agreement for another 11.8%. Those codes that were not in agreement were reconciled by consensus of the two coders.

# Results

## Participant Demographics

The pre-test and posttest survey response rate was 87% and 72%, respectively. While the program was available to individuals across all ethnicities, ages and education levels, many of

the Biotech 101 attendees were older in age (54.1% 61 or older), Caucasian (87.9%), and highly educated (40.8% with graduate degree) (Table 1). However, the gender distribution was almost equal (48.9% male). The most frequently selected reasons for attending the program were an interest in the field of biotechnology (52.2%), seeking more scientific knowledge (63.3%), and an interest in learning more about HudsonAlpha (63%).

Table 1

Pre-test demographic data

| **Demographic** | **Category** | **Frequency** | **Percent** | **Madison County, Alabama[a]** |
|---|---|---|---|---|
| Age | Under 20 | 5 | 1.8 | 27.6 (Under 20) |
| | 21–30 | 7 | 2.5 | 6.9 (20–24) |
| | 31–40 | 13 | 4.6 | 12.4 (25–34) |
| | 41–50 | 36 | 12.9 | 15.2 (35–44) |
| | 51–60 | 52 | 18.6 | 21.0 (45–59) |
| | 61 or older | 167 | 59.6 | 17.0 (60+) |
| Gender | Male | 139 | 49.3 | 48.9 |
| | Female | 143 | 50.7 | 51.1 |
| Ethnicity | American Indian *or* | 4 | 1.4 | 0.7 |
| | Alaskan Native | | | |
| | White | 252 | 89.4 | 68.5 |
| | Asian or Asian American | 12 | 4.3 | 2.2 |
| | Black or African American | 8 | 2.8 | 24.1 |
| | Hispanic or Latino | 3 | 1.1 | 2.9 |

| Demographic | Category | Frequency | Percent | Madison County, Alabama[a] |
|---|---|---|---|---|
| | Native Hawaiian *or* | 0 | 0.0 | 0.1 |
| | Other Pacific Islander | | | |
| | Mixed | 1 | 0.4 | 1.8 |
| | Other | 2 | 0.7 | -- |
| | Some High School | 5 | 1.8 | 9.2 |
| | High School Graduate | 4 | 1.4 | 22.1 |
| | Some College | 29 | 10.3 | 20.2 |
| | College Graduate | 78 | 27.7 | 31.2 |
| | Some Graduate School | 47 | 16.7 | -- |
| | Graduate Degree Completed | 119 | 42.2 | 13.4 |
| Education | Other | 0 | 0 | 4.1 (grade 0–8) |
| | Medical Community | 30 | 10.9 | – |
| | Educational Community | 40 | 14.5 | |
| | Community Organization | 8 | 2.9 | |
| | Science/Technology Community | 72 | 26.1 | |
| | Government | 15 | 5.4 | |
| | Other | 64 | 23.2 | |
| Professional Group | None | 47 | 17.0 | |

a Data retrieved from the US Census bureau 2008 estimates for Madison County, Alabama (http://quickfacts.census.gov) and Madison County Alabama Online 2007 estimates (www.co.madison.al.us/about/dem)

Change in Perceived Knowledge

Many participants reported low levels of perceived knowledge across the topic areas on the pre-test. 2,155 out of the 3,673 total responses (across all respondents) for the 11 topic related questions indicated little or no confidence in the assessed topic areas. Respondents showed the lowest initial confidence in being able to accurately discuss the field of biotechnology and understanding the difference between genetics and genomics. Areas of highest confidence included comprehending biology related news articles as they relate to human health and knowing enough about their families' health histories to make health related decisions.

Posttest data showed a statistically significant increase in perceived knowledge level for all content areas. Particular increases in perceived knowledge were noted for "accurately discuss the field of biotechnology" and "difference between genetics and genomics" for which the number of "not-confident" responses decreased from 188 to 187 on the pre-test to 6 and 8 on the posttest, respectively. Perceived knowledge score was defined as the frequency each confidence level was reported across all participants. A score was calculated for each individual topic area as well as all topic areas combined (Figs. 1 and 2). Mann–Whitney U tests revealed a significant difference in all calculated perceived knowledge scores between the pre-test and posttest (Table 2). Additional perceived confidence level data are provided in the electronic supplementary material (ESM Table 1 and ESM Table 2).

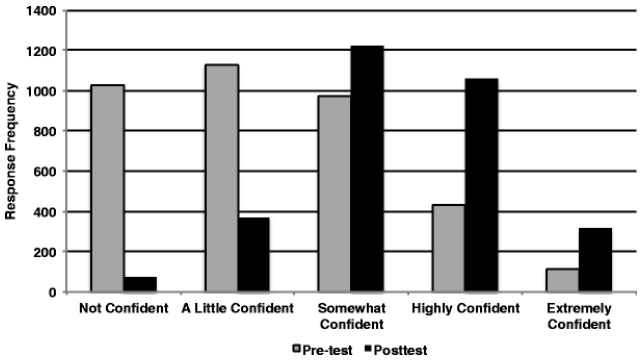


Fig. 1

Change in combined perceived knowledge score from pre-test to posttest. Combined perceived knowledge score is the frequency each confidence level was reported by all participants across all 11 assessed Biotech 101 topic areas. The positive shift in perceived knowledge was found to be statistically significant ($p < 0.01$)

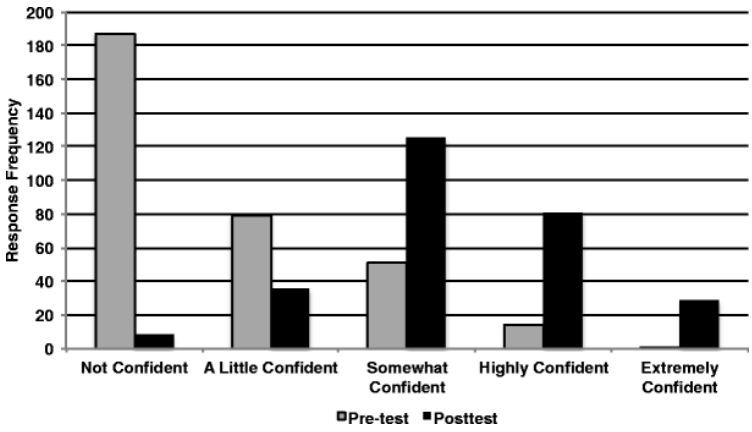


Fig. 2

Change in perceived knowledge for topic area: “I understand the difference between genetics and genomics.” Program participants indicated their confidence level for this topic area on both the pre-test and posttest. The positive shift in confidence was found to be statistically significant ($p < 0.01$)

**Table 2**

Change in median perceived knowledge score for each content area

| **Content Area** | **Pre-test Median** | **Posttest Median** | **U[a]** | **z** | **r** | **N (pre-test and posttest)** |
|---|---|---|---|---|---|---|
| Accurately discuss the field of biotechnology | 1.0 | 3.0 | 10943.5* | −16.934 | 0.686 | 610 |
| Difference between genetics and genomics | 1.0 | 3.0 | 11325.5* | −16.631 | 0.673 | 610 |
| Relationship between genes and physical characteristics | 2.0 | 3.0 | 18433.5* | −13.240 | 0.536 | 610 |
| Use scientific information to support an ethical discussion | 2.0 | 3.0 | 21306.0* | −11.749 | 0.476 | 608 |
| Relationship between genetics and environment | 2.0 | 3.0 | 17445.5* | −13.649 | 0.553 | 609 |
| Comprehend biology related news articles as they relate to | 3.0 | 4.0 | 26582.0* | −9.400 | 0.381 | 609 |

| Content Area | Pre-test Median | Posttest Median | U[a] | z | r | N (pre-test and posttest) |
|---|---|---|---|---|---|---|
| health | | | | | | |
| Know family's medical history to make important health related decisions | 3.0 | 3.0 | 37899.0* | −4.022 | 0.163 | 610 |
| What cancer is and how it spreads | 2.0 | 4.0 | 21155.0* | −12.085 | 0.488 | 614 |
| How antibiotics work and why there are resistant pathogens | 2.0 | 3.0 | 21822.5* | −11.636 | 0.470 | 612 |
| Genetic similarities and differences between variety of plants and animals | 2.0 | 3.0 | 23301.5* | −10.808 | 0.438 | 609 |
| Relationship between biotechnology and modern medicine | 3.0 | 4.0 | 21136.5* | −11.990 | 0.484 | 613 |
| All topic areas | 24 | 37 | 12560.5* | −14.846 | 0.611 | 591 |

[a] Change in median determined by Mann–Whitney *U* Tests

*$p < 0.01$

Impact of the Information

Participants were asked to indicate the impact of the information presented during Biotech 101 on several areas of their lives. For each area, participants were asked to rank the level of impact from one (no impact) to five (large impact) (ESM Table 3). High levels of impact were reported overall, as greater than 80% reported at least "a little impact" for each area. Areas of largest impact were "conversations with family members about health" and "future medical decisions," with 215 and 218 reponses of moderate or large impact, respectively. Lowest levels of impact were reported for "social interactions with others" and "political choices," with 79 and 89 responses of none or little impact, respectively.

The relationship between posttest perceived knowledge and level of impact was investigated using Spearman's rho correlation coefficient (Table 3). A small (rho = 0.075–0.206), positive correlation was observed between the two variables with high levels of perceived knowledge associated with higher levels of impact. This correlation was statistically significant for all impact areas except "social interactions." In addition, there was a larger positive correlation (rho = .285–.636) between high levels of impact in one area and high levels of impact in other impact areas.

Table 3

Relationship between total postscorea and level of impact (Spearman's rho)

| | **Total postscore** | **Everyday life** | **Medical decisions** | **Investment choices** | **Social interactions** | **Political choices** | **Research participation** | **Family conversations** |
|---|---|---|---|---|---|---|---|---|
| Total postscore | – | .206** | .192** | .154* | .075 | .134* | .178** | .179** |
| Everyday life | | – | .636** | .454** | .489** | .420** | .337** | .430** |
| Medical decisions | | | – | .453** | .407** | .434** | .439** | .526** |
| Investment choices | | | | – | .502** | .425** | .285** | .310** |
| Social interactions | | | | | – | .483** | .390** | .412** |
| Political choices | | | | | | – | .444** | .438** |

| | Total postscore | Everyday life | Medical decisions | Investment choices | Social interactions | Political choices | Research participation | Family conversations |
|---|---|---|---|---|---|---|---|---|
| Research participation | | | | | | | – | .497** |
| Family conversations | | | | | | | | – |

[a]Total postscore is the sum of confidence levels across all topic areas for a single participant

**$p < 0.01$; *$p < 0.05$

Likelihood for Future Action

Participants were also asked to indicate the likelihood that they would participate in future learning activities (ESM Table 4). The majority (greater than 95%) of respondents indicated they would be “likely” or “very likely” to recommend Biotech 101 to others, attend other HudsonAlpha events, read more on their own about biotechnology, and attend a Biotech 201 sequel course covering different subjects. The only action that respondents indicated they were not likely to do was return to a future Biotech 101 on the same subjects. The relationship between posttest perceived knowledge and likelihood for future action was also investigated using Spearman’s rho correlation coefficient. There was a small (rho = .246–.254), positive correlation in the data between high total postscore and higher likelihood to read more about biotechnology and attend Biotech 201 (p = <0.01).

Qualitative Data

A total of 327 open responses were returned on the posttests and organized by theme (Table 4). Overall, participants were very satisfied with the Biotech 101 course as 151, 38.5% of all participants, indicated a general appreciation for the course. Forty-three participants expressed a desire for more—more resources provided, more outside reading, addition of hands-on experiences, and for the course be made more widely available (i.e. TV, DVD, Internet). In addition, 30 participants requested the course be extended: both the length of sessions and the number of sessions in each course.

**Table 4**

General themes from open-response questions

| **Theme**[a] | **Response Frequency**[b] |
|---|---|
| General appreciation for course | 151 (38.5%) |
| Desire for *more* | 43 (11.0%) |
| Extend course length | 30 (7.7%) |
| Benefit of program to community | 27 (6.9%) |
| Improvements to course content | 25 (6.4%) |
| Praise for presenters | 23 (5.9%) |
| Desire for future educational opportunities | 18 (4.6%) |

[a]Themes reported 10 or less times excluded from table

[b]Percentage based on 392 total participants across all three course offerings

A significant number (n = 25) of open responses indicated improvements that could be made to the course content. A small number of respondents (n = 5) indicated the course moved too quickly and was too difficult; however, two other individuals wrote that they would like the content to be more technical. Others mentioned specific content areas that they would have liked

more information on—how companies within HA interact, ways to give or invest, ways to get involved with HA, basic science content, and how course content relates to specific diseases.

Many participants (n = 27) commented on the positive impact HudsonAlpha and the Biotech 101 course have on the local community. Twenty-three respondents expressed praise for the course presenters, citing their knowledge-level and enthusiasm, and eighteen participants commented that they were looking forward to attending future events and course offerings. One person wrote, “Would like to know that there will be other presentations of 102-3-4-. Everyone is always interested in new discoveries and advances—the program was very conducive to a learning environment.” It is of note that five respondents commented specifically that they were planning to recommend the course to others. One participant wrote, “Wonderful experience. I’m telling all my friends and family plus my M.D.”

## Discussion

This study successfully evaluated the Biotech 101 program and results show that Biotech 101 is an effective mechanism for increasing the genetic literacy of program participants. The overwhelming interest in the program among the local community shows that Biotech 101 is meeting a previously unmet educational need. Through the Biotech 101 program, many community members are being exposed to current topics in genetics and biotechnology. The knowledge gained through participation in the course increases genetic literacy as well as helps participants think more critically about scientific topics and be a more informed health consumer. Participants overwhelmingly indicated satisfaction with the program in both logistics and presentation.

Content areas that showed the largest increase in confidence included being able to discuss the field of biotechnology and understanding the difference between genetics and genomics. Having a working knowledge of these content areas is important for the general public, as medicine becomes increasingly driven by genomic data. In addition to an increase in knowledge confidence, most participants reported that attending Biotech 101 had at least “some impact” on their lives highlighting the importance of genetic literacy beyond simply increasing content knowledge. An increase in genetic literacy impacts an individual’s life, relationships, and decisions. Results from this study reinforce this hypothesis, showing an association between increased levels of perceived knowledge and increased impact and likelihood for future action.

In a field that changes as rapidly as genetics, it is impossible to provide the public with all the background information they should know, or keep the public up to date on every important discovery. Therefore it is important to give program participants the tools and skills necessary to continue life-long independent learning about genetics and biotechnology. Biotech 101 participants indicated a strong interest in continued learning through other educational events and reading, and were provided with a list of suggested resources and outside reading materials.

More than 97% of posttest respondents reported they would be likely or very likely to attend a future education series on different subjects. Graduates of the first three Biotech 101 courses were invited to attend Biotech 201 held in winter 2010. Of these 372 individuals, 283 (76.1%) registered for the first offering of Biotech 201, supporting the notion that this program encourages life-long learning, a key component of genetic literacy.

The high response rates observed in this study indicate the evaluation data likely represents the overall population of Biotech 101 participants. Program participants comprise a highly self-selected group interested in learning more about genetics and biotechnology. The outcomes observed cannot necessarily be generalized to society at large, but subpopulations similar to that attending Biotech 101 exist nationwide. The data presented in this study shows that Biotech 101 meets the educational needs for this population, and potentially similar populations in other communities. Biotech 101 will continue to be offered by HudsonAlpha Education Outreach each fall. We expect to reach approximately 275 new community members each year through this course.

We have used our experiences and participant feedback to make improvements to the program. After the first course offering, it was apparent that we needed a bigger venue and more time, so the program was moved to the larger Jackson Center and extended from four weeks to five. One major factor we believe that has contributed to the program's success is targeting a lay audience using understandable vocabulary and minimizing jargon. Other important factors have been including a mid-session break, a desirable program location (on the HudsonAlpha biotech campus), and word of mouth advertising. Many of our attendees have encouraged their friends, family members, and health care professionals to attend the course. Scientists are ideally suited to help local communities understand concepts and current topics in the areas of genetics, genomics and biotechnology. The Biotech 101 program and its evaluation methods can serve as a model for other groups developing similar public education initiatives.

Limitations

There are specific limitations to this study that reduce its generalizability to other populations and provide opportunities for further research. Most notably, the survey instrument design lacked questions that measured knowledge gain directly and did not undergo rigorous validity and reliability testing. This decision to use self-perceived knowledge was made largely to avoid undesired anxiety and intimidation among survey respondents. While the measurement of self-perceived knowledge can lead to an overestimation of actual knowledge due to the 'illusion of knowing,' it has been found that it is most problematic when baseline perception of knowledge is high (Epstein et al. 1984). Our participants had low baseline perceptions of knowledge, making an overestimation of knowledge due to the 'illusion of knowledge' less likely. An increase in

self-perceived knowledge, or high self-precepts of efficacy, in a particular topic area has a positive impact on a person's ability to face new challenges (Bandura 1982).

Additionally, no control group was surveyed that would have provided a direct comparison group to ensure changes in perceived knowledge gain was due to participation in Biotech 101. The presence of demand characteristics may play a role in artificially increasing positive responses on the survey. Participants may have formed an opinion that is positively biased due to their desire to continue Biotech 101 offerings in the future or unintentionally interpreting the purpose of the study.

The demographic characteristics of program participants were not equally distributed, nor representative of the larger Madison County, Alabama. There are several possible explanations for this discrepancy such as the time commitment and advertisement method. The course is advertised primarily though HudsonAlpha events, email distribution lists, public radio, newspaper and word of mouth. Advertising in other venues might influence the demographics and bring in a more diverse audience. More research is required to determine the specific explanation for the unbalanced demographics. Due to the small sample sizes in many of the demographic categories, it was not possible to assess the relationship between demographic groups and other variables.

## Future Research

Additional research is necessary to address the previously mentioned limitations. Specifically, a validated and reliable content knowledge instrument needs to be developed and administered in future offering of Biotech 101. Administration of such an instrument and conducting focus group interviews would provide a more comprehensive assessment of learning as a result of Biotech 101. Additionally, a matched control group should be established and provided the same validated content instrument to establish a direct comparison group. Future interactions with Biotech 101 participants will make it possible to conduct longitudinal studies measuring the long-term impact of knowledge gain as a result of participation. Continued research in public knowledge gain through interactions in free course offerings by research institutes such as HudsonAlpha's Biotech 101 add to the currently limited evidence-base found in the literature regarding public education strategies in genetics.

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**Electronic supplementary material is omitted from this formatted document.**

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