



Biotech-Careers.org: A Resource for Building Career Awareness in Biotechnology

SANDRA PORTER^{1*}, KAREN LEUNG², AND TODD SMITH¹

¹Digital World Biology, Seattle, WA 98107, USA

²Biotechnology Program, City College of San Francisco, San Francisco, CA 94112, USA

*sandra@digitalworldbiology.com

Abstract: Biotech-Careers.org is a comprehensive career information resource used in college and high school classrooms nationwide. The site combines education materials and job search capabilities with an extensive employer database. We describe four paths for exploring Biotech-Careers.org—People, Places, Things, and Jobs and describe the impacts of using the site on multiple cohorts of college students. The students reported an increased interest in pursuing biotechnology-related careers and an increase in cognitive factors (awareness, belonging, self-efficacy, and identity) known to be important in career choice.

Keywords: biotechnology, career, awareness

© 2023 under the terms of the J ATE Open Access Publishing Agreement

Introduction

Biotechnology companies have a wide variety of positions, pay well, provide good benefits, and offer opportunities for advancement and job satisfaction. Yet, despite these advantages, industry reports highlight the challenges companies face with finding enough qualified employees [1, 2].

Two factors contributing to this problem are a lack of awareness of what people do in biotechnology and an absence of clear pathways for embarking on biotechnology careers. When it comes to biology-oriented professions, most students know what doctors and nurses do. Many can even guess what a medical technician's job might be like. But when it comes to biotechnology, the job titles are mysterious, the work responsibilities unclear, and the pathways for learning the required skills and embarking on those careers are invisible. For example, how would a student know the difference between a Research Assistant, Research Associate, and Scientist? How could they know what kinds of tasks are performed by Process Development Associates, Quality Control Associates, Manufacturing Technicians, Data Managers, Validation Engineers, and Project Managers and what the educational pathways might entail?

Biotech-Careers.org was designed to address the challenge of describing entry-level biotechnology careers. We describe educational materials at the site, discuss four pathways for student exploration, and present student data demonstrating increased career awareness and other cognitive factors related to career choice after students have used the site.

1.1 Biotech-Careers.org

Biotech-Careers.org is a multi-media online resource where students can learn about different industry sectors and find position titles, career descriptions, maps, companies, job postings, videos, and programs that can prepare them to enter the biotechnology workforce (Table 1).

The site was created by Digital World Biology (DWB) as part of the National Bio-Link Center for Biotechnology Education [3] and launched in June 2012. Since the end of Bio-Link in 2018, DWB has continued adding features and content through a grant (DUE 1764225) from the National Science Foundation's Advanced Technological Education (ATE) program. DWB also collaborates with the current National ATE Center for Biotechnology, InnovATEBIO, as a leader for the Biotech-Careers.org and Entrepreneurship Hub [4].

The site addresses a common misperception that biotechnology careers require advanced degrees by including profiles from community college alumni and hiring data from InnovATEBIO. Alumni from biotechnology programs nationwide contributed descriptions of their educational journeys and daily routines along with photos showing what their work is like [5]. In addition, 96 InnovATEBIO community college programs contributed hiring data [6]. These stories and data demonstrate that a wide variety of people at multiple education levels work in biotechnology companies and that the industry values community college certificates and degrees.



Table 1. Career education resources at Biotech-Careers.org

Link Title	Career Education Resource	Number
Career Descriptions	Descriptions of entry-level positions in biotechnology – include average salary, education, degrees, colleges	33
Job Areas	Job descriptions in different business sectors	36
People	Profiles of community college alumni working in industry	35
Blogs	Articles on the biotechnology industry and new careers	59
Videos	Videos about working biotechnology	70
Biotech Companies	Interactive maps show a global view of company locations, companies in the United States, or company locations organized by state. Company profiles contain a short description, a link to the company's website, and indicate whether the company has hired a student from a two-year college. In addition, direct links to company career and internship pages are included.	>8828 ^a companies in >12,488 locations
Biotech Jobs	Links to two job board databases allow visitors to search job posts. Searchable lists of employer career pages and internship pages are also provided.	>3963 US employer career pages >99 US employer internship pages in 191 locations
Business Areas	A word cloud displays terms companies use to describe their activities. Each term is linked to a page with an interactive map of the company locations and table with companies working in one area.	>507

^aThe number of companies and business areas is dynamic and changes almost daily.

1.2 The Biotech-Careers Industry Database

DWB added a biotechnology industry database to Biotech-Careers.org in 2016. The database represents a wide variety of employers worldwide that produce biotech and biopharma-related products, technology, and services. We use Google (Google.com) to search for company names and gather data from company websites to add companies to the database. For each company, we enter locations, a description, URL, the company's business areas, and whether they have hired a community college student. We enter most of the data manually, averaging 100 companies per month. Tabular data are imported using the Drupal Feeds module [7].

We use automated tools to check company URLs once a year to maintain and curate the database. Automated tools are also used more frequently to obtain and add links to career and internship pages. Companies with problem URLs are reviewed and either unpublished or updated. Since 2016, we have unpublished 1786 companies that either went out of business, were purchased, or merged with another company.



We obtain company names from multiple sources. These include CrunchBase [8], the Biotechnology Innovation Organization (BIO) membership list (BIO.org), and trade association websites [9-12]. In addition, we use scientific journals such as Nature (Nature.com), Science (Science.org), and Nature Biotechnology (Nature.com/nbt); newsletters: 360Dx (360dx.com), GenomeWeb (GenomeWeb.com), STAT news (STATnews.com), Fierce Biotech (FierceBiotech.com), Endpoints news (Endpts.com), Genetic Engineering & Biotechnology News (genengnews.com), Geekwire (Geekwire.com), BioBuzz (Biobuzz.io), SynBioBeta (Synbiobeta.com); and newspapers: the Seattle Times (Seattletimes.com), and the New York Times (nytimes.com). Companies also fill out forms on our website requesting to be added.

InnovATEBIO programs are an essential data source [13]. These data are used to identify companies that have hired community college students. As of February 2023, at least 732 of the 6639 U.S.-based employers (11%) hired students from InnovATEBIO community college programs [14]. The map of companies that have hired community college students illustrates that students from InnovATEBIO programs are being hired by large and small companies throughout the US.

1.3 Insights from the Industry Database

Biotech-Careers.org does not claim to include every biotechnology company in the world or even in the U.S. With 8,828 employers, Biotech-Careers' database is larger than the BIO membership list (1473) [15], smaller than BiotechGate (21,565 companies) [16] and close in size to the IBIS World report (11,076 businesses worldwide) [17]. Two outliers are CrunchBase (41,855) and the TEConomy/BIO report (127,000) [18]. These values are higher because CrunchBase includes companies that have gone out of business, and the TEConomy/BIO report derives company numbers from NAICS codes. NAICS codes are a standard used by the government for classifying businesses. These codes have well-documented problems when it comes to biotechnology [19].

No database is perfect. Even so, the company database provides insights into the biotech industry. Interactive maps visually demonstrate that biotechnology is a worldwide industry and that companies cluster in specific locations. In addition, business terms show that biotech-related companies work on a wide range of topics.

The top ten business areas in the database are shown in Table 2. Except for COVID-19, the top six, from Small Molecules to Antibodies, are well-known topics in biopharma. Newer technologies such as Cell and Gene Therapy and Synthetic Biology are also represented.

Table 2. Top Business areas Represented in Biotech-Careers.org

Business Area	Number of Companies	Locations Worldwide
Small Molecules	697	1151
COVID-19	620	1207
Therapeutics	533	821
Diagnostics	512	750
Medical Devices	474	776
Antibodies	476	928
Cell and Gene Therapy	422	681
Synthetic Biology	401	507
Bioinformatics	328	409
Cancer Therapeutics	291	473

Choosing a topic from the Business Areas page shows a further breakdown of areas that describe company activities (Fig. 1). For example, companies that work on Small Molecules also work on other Therapeutics (Biologics, Cancer, Antibodies, Immunotherapy), and related areas such as Drug Discovery and Vaccines.



Companies Working with Small Molecules also Work in 153 Other Areas:

Therapeutics (57) | Biologics (50) | Cancer Therapeutics (47) | Drug Discovery (36) | Antibodies (29) | COVID-19 (29) | Cancer (25) | Immunotherapy (19) | Neurobiology (18) | Vaccines (17) | Immunology (16) | Rare Diseases (16) | Cell and Gene Therapy (15) | Generics (13) | Diagnostics (12) | Epigenetics (12) | Metabolism (12) | Inflammation (11) | Alzheimer's (10) | Microbiome (10) | Oncology (10) | Cardiovascular (9) | Pharmaceuticals (9) | RNA (9) | Antivirals (8) | Drug Delivery (8) | Infectious Disease (8) | Pain Management (8) | Protein Degradation (8) | Artificial Intelligence (7) | Autoimmunity (6) | Parkinson's Disease (6) | Protein Kinase (6) | Vision (6) | Antibiotics (5) | Biomarkers (5) | Chemistry (5) | Contract Research (5) | Liver Disease (5) | Medical Devices (5) | Peptides (5) | T-Cells (5) | Biopharmaceuticals (4) |

Figure 1. Subdivisions of business areas in Biotech-Careers.org. These data are from 697 companies that work on small molecules. The numbers in parentheses show the number of small molecule companies working in each business area.

1.4 Pathways for Exploration

Students who visit Biotech-Careers.org are likely to have different goals and interests depending on where they are in their educational careers. To reach students of different ages and interests, we developed four pathways for exploring the site: People, Places, Things, and Jobs (Fig. 2).

College students, who are already interested in biotechnology, might prefer starting with Jobs or Places to quickly learn about companies in their area, what they do, and the kinds of jobs available. Students at an earlier stage, such as high school students, might prefer reading about the People working in different careers or learning about the kinds of Things that companies make or the topics they work on.

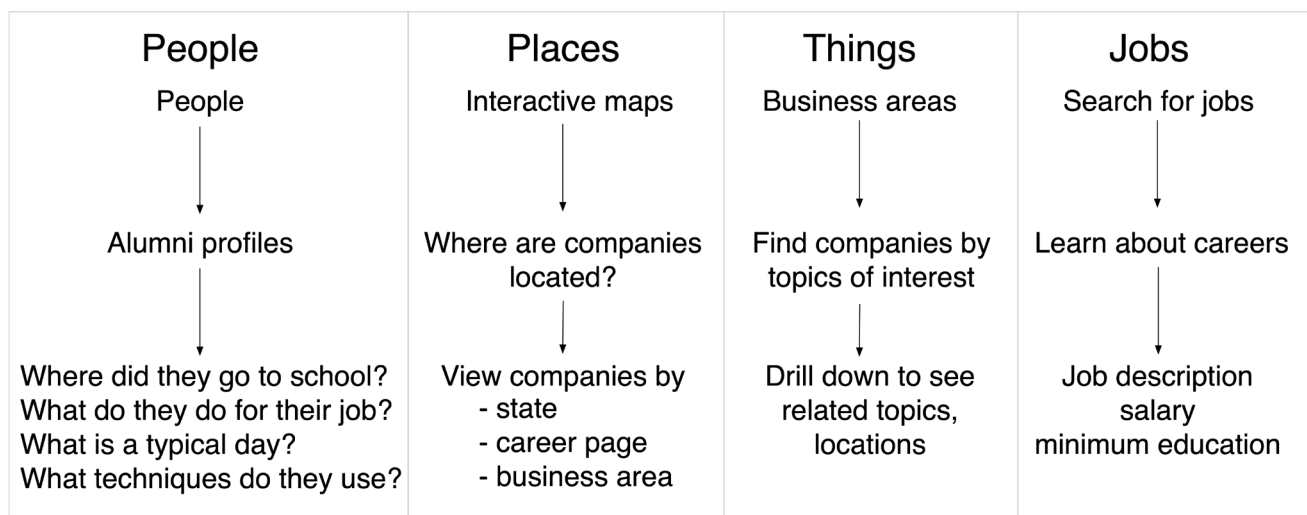


Fig. 2. Four paths for exploring Biotech-Careers.org.



To learn about people working in biotech (Fig. 3), students select People to view profiles of community college graduates working in biotechnology. They choose a person to read about, learn where they went to college, what a typical day on the job is like, and see the kinds of degrees or certificates they obtained. They can follow links to job areas or career descriptions from an alumni profile. Job areas organize content around different business sectors, such as genomics or synthetic biotechnology. This section contains links to videos, articles, profiles, careers, and more. Visiting the Careers page displays cards linked to descriptions of different jobs. These include the average salary across the US, the minimum education needed, a job description, links to view available positions, and links to InnovATEBIO programs that prepare students for these careers.

The Biotech Companies link opens a page for exploring biotechnology through Places (Fig. 4). There are links to explore companies worldwide, the entire United States, or specific states. Interactive maps show over 12,000 company locations, 8,341 in the US.

Individual state maps show students, through word clouds of the top business areas (Fig.4, right side), that the distribution of companies working in different business areas varies from state to state. Students can use the buttons under Career Information and Internship Information as filters to select companies that provide this information on their websites. Companies with career information on their websites are more likely to be hiring.



Navigation bar: Careers Job Areas B **1** People Videos Biotech Companies Biotech Jobs Business Areas

Research Associate

Kevin Hin works as a Research Associate at Acepix Biosciences in Hayward, California. He manages ... [Read more](#)

Computational Biology / Genomics - Research Associate

Milana Cybert, Research Associate at the Translational Genomics Research Institute (TGen), describes her work and ... [Read more](#)

Cell Culture - Lab Supervisor

Seravin Behnken is the Lab Supervisor at the cell culture core lab at the Fred ... [Read more](#)

Immunochemistry - Research Associate

Jessica Zabloski, Research Associate at Bio Scientific Corp. tells us about making ELISA kits. [Read more](#)

DNA Sequencing Technician

Cagney Coomer has been working as a sequencing technician at the University of Kentucky Advanced ... [Read more](#)

Laboratory / Manufacturing Technician

Julian Gutierrez works as a Lab / Manufacturing Technician at Biotility in Florida. He tracks ... [Read more](#)
Sponsored by: Biotility

Research Assistant - Graduate Student

The image shows Elizabeth Clawson, a graduate of Madison College, WI, working in the Biological ... [Read more](#)

Wastewater analyst

Veronica Benites works for Cel Analytical analyzing potable, recreational, and waste water. She shared her ... [Read more](#)

2

Making media

Veronica Benites works for Cel Analytical analyzing potable, recreational, and waste water. She shared her insights about her work and education.

What biotechnology program did you attend?
I attended the Bridge to Biotechnology program at the [City College of San Francisco](#) (CCSF), San Francisco, CA
I also completed the [Laboratory Assistant program](#) at [City College of San Francisco](#).
Before attending City College, I completed a B.S. in Chemistry in Brazil.

What degree/certificate are you working towards?
[Associate of Applied Science, Biotechnology](#)

What do you do for your job?
I perform Potable, Recreational, and Wastewater testing for bacteria and some inorganic chemistry assays following the EPA's (Environmental Protection Agency) requirements towards Environmental Monitoring/Protection.

What are some techniques that you commonly use?
• aseptic technique

Fig. 3. Exploring careers through People. Students begin by selecting an alumni profile and reading about that person's educational journey. From there, students can choose from multiple resources such as videos, articles, profiles, and career descriptions.



Careers Job Areas Blogs People Videos **Biotech Companies** Biotech Jobs Business Areas

Biotech Company and Employer Location Maps

Search

Biotechnology is a worldwide business. The Biotech-Careers biotechnology, pharma, and medical device company directory has 8,787 potential employers - engaged in 563 business activities - that are located in 12,312 sites throughout the world. Use the maps below to view biotech employer locations in specific states, the United States or the world.

2

Mouse over and click on a state to view the employers in that state. Click the image or view the data as a table organized by state. Click the image or view the data as a table organized by country.

Washington Biotech Companies and Employers

339 potential employers in a total of 354 locations.
View the biotech employers in Washington [as a table](#)
View biotechnology education in [Washington](#)

Brick red icons = schools; Light blue icons = employers

Community College Hire	Career Information	Internship Information
<input type="radio"/> Reset	<input checked="" type="radio"/> Reset	<input checked="" type="radio"/> Reset
<input type="radio"/> Yes	<input type="radio"/> Yes	<input type="radio"/> Yes

Filter By Employer Name By Business Area

Top Business Areas

- Medical Devices
- Therapeutics
- Cancer Therapeutics
 - Antibodies
 - COVID-19
 - Immunotherapy
 - Immunology
- Cell and Gene Therapy
- Small Molecules
- Bioinformatics
- Diagnostics
 - Food
 - Molecular Diagnostics
 - Research
- Artificial Intelligence
- Synthetic Biology
 - Vaccines
- Agriculture
- Contract Research
- Genetic Testing
- more

Fig. 4. To explore careers by the Place path a student can look at companies on a US map or choose a state. Zooming in shows if there are companies in areas of interest to students.

For the Things path (Fig. 5), we recommend asking students to spend a few minutes jotting down topics of interest. Then, for the next five minutes, they can share those items with the class if they choose. At this point, students can choose Business Areas to see a page with columns showing links to Business Areas, Job Areas, and a list of Entry-level Jobs.

The Business Areas word cloud in the far-left column is derived from over 507 business activities companies use to describe themselves. In each case, the size of a word corresponds to the number of database companies that work in that area. The list is long, but students will likely find terms connected to topics of interest. Some examples are Biofuels, Cancer, Climate tech, Cosmetics, Fashion, Food, Pets, Regenerative medicine, Sporting goods, and Women's Health.



Selecting a Business Area leads to a page with a map and directory of all the companies in the database that work in that area. They can see where those companies are located, look at individual company descriptions, and visit company web pages to learn what they do and whether they are hiring.

[Careers](#) [Job Areas](#) [Blogs](#) [People](#) [Videos](#) [Biotech Companies](#) [Biotech Jobs](#) **[Business Areas](#)**

Business Areas - Job Areas - Careers

Top 100 Terms: Click the image to see it full size.

Business Areas
 3D cell culture · 3D Printing · AAV · Acquisitions · Adenovirus · Adjuvants · ADME-tox · Aeroionics · Aerospace · **Agbiotech** · Aging · **Agriculture** · Agtech · **Algae** · Allergy · ALS · **Alzheimer's** · Anaerobe · Microbiology · Analytical Chemistry · **Analytical Services** · Ancestry · Animal Care · Animal Models · **Animal Nutrition** · Antibacterials · **Antibiotics** · **Antibodies** · Antifungals · Antigens ·

Job Areas
Agricultural biotechnology · **Animal biotechnology** · Aquaculture, Biodefense, **Biofuels**, **Biomanufacturing**, **Biomaterials**, **Biopharmaceuticals**, **Bionrocessing**

Entry-level Jobs

- Agricultural and Food Science Technician
- Animal Technician
- Biofuel Technician
- Biomanufacturing Technician - Downstream
- Biomanufacturing Technician - Upstream
- Cell Culture Technician
- Chemistry Quality Control Technician
- Clinical Research Associate
- Compliance Specialist
- Environmental Health & Safety Technician
- Environmental Science and Protection Technician
- Facilities Technician
- Food Sample Inspector

2 [Antibody Companies and Organizations](#)

[View Jobs](#) [View More Jobs](#)

Companies working with Antibodies also work in 169 other areas:
[Immunology](#) (99) | [COVID-19](#) (72) | [Therapeutics](#) (65) | [Cancer Therapeutics](#) (55) | [Immunotherapy](#) (47) | [Biologics](#) (37) | [Reagents](#) (29) | [Cell and Gene Therapy](#) (26) | [Small Molecules](#) (26) | [Vaccines](#) (23) | [Synthetic Biology](#) (19) | [Autoimmunity](#) (18) | [Proteins](#) (18) | [Contract Research](#) (15) | [Immuno-oncology](#) (14) | [T-Cells](#) (13) | [Cancer](#) (11) | [Diagnostics](#) (9) | [Immunoassays](#) (9) | [Biomarkers](#) (8) | [Contract Manufacturing](#) (8) | [ELISA](#) (8) | [Assays](#) (7) | [Biomanufacturing](#) (7) | [Cell Culture](#) (7) | [Cell Lines](#) (7) | [Chemistry](#) (7) | [Oncology](#) (7) | [Peptides](#) (7) | [Artificial Intelligence](#) (6) | [Bioinformatics](#) (6) | [CAR-T](#) (6) | [DNA/RNA](#)

264 Employers in 896 Locations

View By: Geography
 World
 United States

Career Information
 Reset
 Yes

Internship Information
 Reset
 Yes

Fig. 5. The Business Areas path enables students to explore biotechnology companies by the things they make and the business areas they focus on.



The Jobs path begins at the Biotech Jobs link (Fig. 6). Selecting the orange “Search for Jobs” button shows the current number of biotechnology jobs within 25 miles of the user’s location. The location, search terms, and distance can all be changed. For example, changing the location to the US on June 6th, 2022, showed 11,802 biotechnology jobs.

In presentations, we stress that these job postings are one example and are supplied by a third-party company that updates data daily. Every job board from LinkedIn (Linkedin.com) to Monster (Monster.com), Indeed (Indeed.com), and Glassdoor (Glassdoor.com) will have a different data set and provide different results. We recommend students use a variety of sites when they begin a serious job search.

Careers Job Areas Blogs People Videos Biotech Companies **Biotech Jobs** Business Areas

Biotech Jobs

1

Working in Biotechnology

Biotech-Careers.org provides three ways to find jobs:

1. Use databases to **Search for Jobs** with key words and location
2. Browse **Featured Jobs** from our sponsors
3. View **Employer Career & Internship** pages

Use databases **Search for Jobs** 2

Job Search

Welcome to the Biotech-Careers Biotechnology Job Board. This page allows you enter terms and a location (City, State). If US is used as a location, jobs for the entire United States are displayed.

If a the prefilled term, or one you have entered, does not provide results, try these terms:

[Biotechnology](#) | [Biomanufacturing](#) | [manufacturing biotech](#) | [manufacturing pharma](#) -- And try our [other job search page](#).

biotechnology US 25 miles **Find Jobs**

Total Jobs: 9705
Jobs Displayed: 500

Research Associate
Genesis Biotechnology Group - Sunnyvale, CA, USA
4 days ago
Summary Comparative Biosciences, Inc (CBI) a part of Genesis **Biotechnology** Group is in need of a Research Associate that will assist and execute scientific studies performed at CBI. This will include ...

Biological Research Associate
Genesis Biotechnology Group - Hamilton Square, NJ, USA
4 days ago
Genesis **Biotechnology** Group (GBG) is a consortium of entities and institutes, in the field of molecular biology, medicinal chemistry and **biotechnology**. Our mission is to improve the patient's quality ...

Research Associate I or II
Cyrus Biotechnology - Seattle, WA, USA
15 days ago
Formed out of the University of Washington, Cyrus **Biotechnology** is a discovery-stage **biotech** with a unique protein design and engineering platform powered by world-leading software capabilities and ...

Equity Research Associate - Biotechnology
Jefferies - Boston, MA, USA
1 month ago
Top investment bank is seeking an equity research associate to support senior **biotechnology** analyst covering mid- and small-cap companies out of our Boston office. Responsibilities Will Include

Equity Research Associate - Biotechnology
Jefferies - New York, NY, USA
1 month ago
Jefferies is seeking an equity research associate to support a senior **biotechnology** analyst covering mid and small cap companies. Responsibilities will include: * Conducting proprietary research ...

Research Associate I/II - Simply Biotech - 16739
Simply Biotech - San Diego, CA, USA
yesterday
Research Associate I/II - Simply **Biotech** OVERVIEW Are you looking for a new career opportunity with an exciting company?! Then we've got the right team for you! In this role, you're responsible for ...

Fig. 6 The Jobs path allows students to search for available jobs by industry sector and location.



Results from students

The many resources at Biotech-Careers.org have made the site popular with both high school and community college educators. We use StatCounter (statcounter.com) and Google Analytics (analytics.google.com) to obtain and analyze statistics from our weblogs. In 2021 and 2022, the site had over 400,000 unique visits annually.

We determined that 20-25% of these visits came from classrooms by looking at referrals, IP addresses, and usage patterns. Referrals from learning management systems often include names that indicate they came from Canvas, Blackboard, Google Classroom, Schoology, or a school district. A typical classroom visit will appear in the weblogs as several independent visits within a short time from the exact location, with a referrer that contains the word “assignment” or a URL such as “classroom.google.com.”

We should note that the number of classes using Biotech-Careers.org has most likely resulted from our work since 2012 in promoting the site and giving presentations for teachers at national conferences such as the Bio-Link Summer Fellows Forum (2012-2018), the National Association for Biology Teachers (NABT), and in online webinars organized by NABT and InnovATEBIO. These events were attended by college instructors and high school teachers, giving us a unique opportunity to inform teachers about the site.

The realization that approximately 100,000 students use Biotech-Careers.org annually made us interested in learning whether using the site influences students’ perceptions of biotechnology careers. To address this question, we gave virtual demonstrations of Biotech-Careers.org to four cohorts of students from a Hispanic Serving Institution (HSI), City College of San Francisco (CCSF), during 2020-2023, as part of CCSF’s Career Exploration in Bioscience course. All the presentations and class sessions were synchronous through Zoom.

For each presentation, we followed the outline below:

- 15 minutes - Walkthrough the four paths for exploring Biotech-Careers.org (People, Places, Things, Jobs).
- 15 minutes – Students chose a path and explored the site independently. Each student was assigned to identify at least one career on the site related to an area of biotechnology that interests them.
- 15 minutes – Students met in Zoom breakout rooms (2-4 students per room) and discussed careers they found interesting.
- 15 minutes – Whole class questions and discussion.

Students were asked to complete a short survey after working with the site. The survey included questions designed to measure changes in awareness, self-efficacy, sense of belonging, and identity. Examining cognitive factors related to career choice helps educators better understand why students might choose one path over another. Awareness is essential since it would be difficult to consider a career without knowing it exists. Self-efficacy, outcome expectations, and student goals have been identified as other important factors [20, 21]. Self-efficacy describes a student’s perceived ability to be successful. Outcome expectations are related to a sense of belonging and identity [22].

After using the site, 97% (64/66) of the students were more aware of the variety of careers in biotechnology (Fig. 7).



How aware were you of the variety of biotechnology jobs BEFORE visiting Biotech-Careers.org and NOW (after visiting the website)? (n = 66)

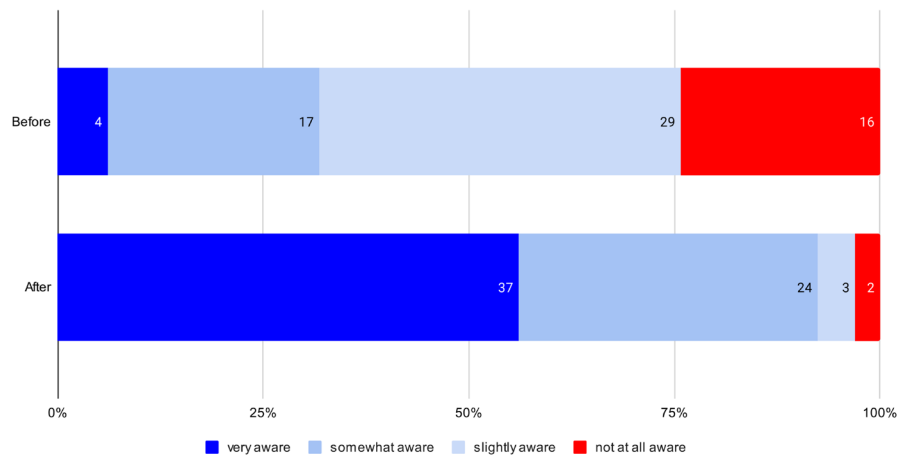


Fig. 7. Student awareness of biotechnology jobs before and after using Biotech-Careers.org.

Most students (51/55) agreed that using Biotech-Careers.org increased the likelihood of pursuing biotechnology as a career (self-efficacy). Students also agreed that they were better able to picture themselves in a biotechnology career (55/57) (belonging) and that visiting the site broadened their ideas about who can be successful in a biotechnology career (56/58) (identity).

Effects of visiting Biotech-Careers.org

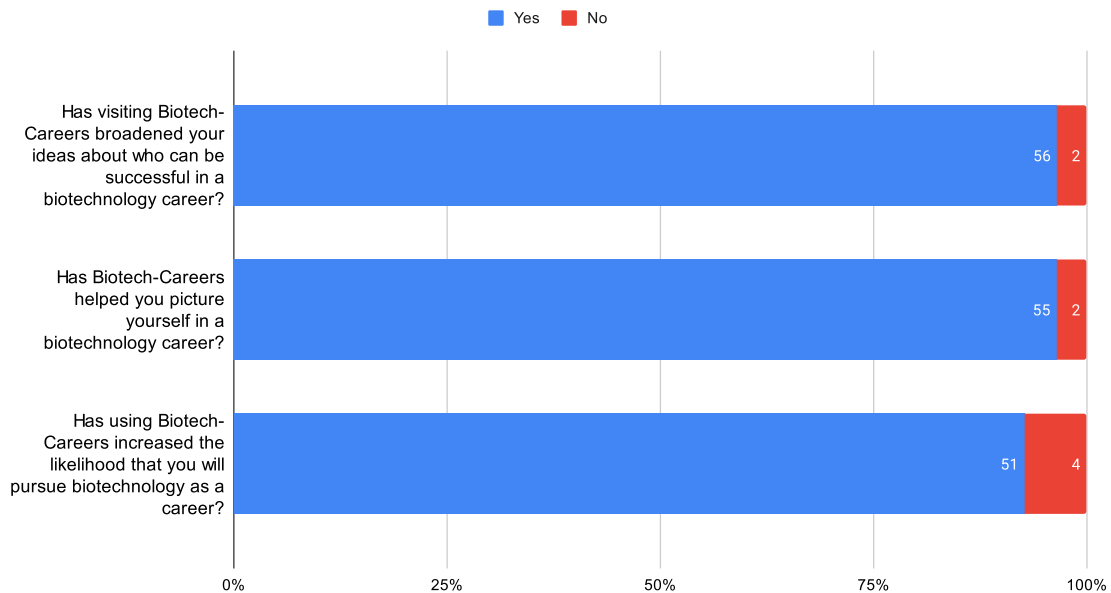


Fig. 8. Student attitudes after using Biotech-Careers.org <<http://biotech-careers.org/>>

Discussion

We launched Biotech-Careers.org in 2012 in response to requests from members of the Bio-Link community. At that time, most career websites made it seem like all biotechnology jobs required a Ph.D. Even now, three of the top four results from a Google search for biotech career information are sites where the information is inaccurate or incomplete [23-25]. One site [23] stated that a bachelor's degree is the minimum requirement for a biotechnology job. Two of the sites [23, 25] obtained misleading data from the US Bureau of Labor Statistics (BLS.gov), causing them to categorize job titles such as Biochemist/Biophysicist, Biomedical Engineer, Agricultural Engineer, Epidemiologist, Animal Scientist, and Soil and Plant Scientist as technicians. While biotechnology companies may employ people in these roles, these scientists in these roles often have a PhD



or Master's degree and are not considered technicians. All three sites missed common positions such as jobs in bioprocessing, kitting, or validation.

Unlike the other sites in the top four Google results, Biotech-Careers.org is unique in that the career descriptions and the information come from people who have worked in the biotech industry. Biotech-Careers.org focuses on entry-level technical positions, many of which can be filled by a person with an associate degree. Many of the original career descriptions were based on a publication [26], co-sponsored by Bio-Link, that is still relevant today. Other descriptions have come from industry contacts and job postings. The site is maintained and updated by subject matter experts with thirty years of experience who are active in the industry.

We have presented an overview of the Biotech-Careers.org website, described how the site might be used in education, and presented results from students who have used the site in class. The website is easy to use and a free resource for students from high school through college. It can be used in synchronous and asynchronous formats to enhance awareness and understanding of the breadth of available biotechnology careers. For example, Michael Fuller, an InnovATEBIO team member from BABEC, uses the site as part of an introduction to biotech activity with high school students. Fuller's approach and slides are available at Biotech-Careers.org [27].

One of us [Dr. Leung (CCSF)] uses an assignment where students research different entry-level jobs and discuss them with each other. Alternatively, a jigsaw activity can be used (either in person or in virtual breakout rooms), where students research one career through the website and then interview each other to learn about those positions. One of our favorite activities is a cocktail party. Students research careers and then participate in a "cocktail" party (with non-alcoholic drinks). They are tasked with making small talk and describing their careers to other students at the party. Other instructors have had students make posters describing different types of biotech jobs. Materials and guidelines for these activities can be downloaded from Biotech-Careers.org [28].

Our studies thus far have focused on college students. In the future, we will present the site to high school students to learn more about the impact of Biotech-Careers.org on career choice in this demographic. Some of us remember being advised against biology as a study topic in college because it was common knowledge that there "were no jobs in biology." As a result, students may stay away from subject areas unless they believe there are attainable jobs. Conducting real-time job searches in an assignment demonstrates that jobs are there and that entry-level jobs don't all require a bachelor's degree or a Ph.D. Convincing students that jobs exist and are attainable may be an essential part of the message.

We are also exploring methods for demystifying career paths. For example, we are currently building a database of skills and linking that information to college programs and jobs to help students better understand what they need to know and where to acquire the appropriate knowledge and skills.

Conclusion

Biotech-Careers.org is a comprehensive resource for career education that can launch many career exploration activities. We found that using the site positively impacted students' awareness and interest in biotechnology careers and their ability to picture themselves working in a biotechnology career. Including an industry database shows where students are likely to find positions working in the industry. The job search feature provides additional, timely information about the skills and knowledge that employers seek.

Acknowledgments. We thank Candiya Mann and Adam McKee for their evaluation services and data analysis. This work was funded by a grant from the National Science Foundation (DUE 1764225). Grants from the National Science Foundation's Advanced Technological Education program (DUE 0903307, DUE 1400721, DUE 1764225) provided the initial funding for developing, maintaining, and adding content to the site. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Disclosures. The authors declare no conflicts of interest.

References

- [1] "MassBio 2022 Industry Snapshot," <https://readymag.com/MassBio/2022IndustrySnapshot/toc/>.
- [2] "2021 Life Sciences Workforce Trends Report: Taking Stock of Industry Talent Dynamics Following a Disruptive Year," <https://www.csbioinstitutes.org/workforce-development>.



- [3] E. A. Johnson, "Bio-Link: Educating the Biotechnology Workforce Using Resources of Community and Technical Colleges." *Biochem. Mol. Biol. Educ.* 31, 348-351 (2003).
- [4] T. Smith, H. Bock, J. Hewlett, et al., "Introducing the NSF-ATE InnovATEBIO National Biotechnology Education Center," *J Biomol Tech.* 31(Suppl) S29-S30, (2020).
- [5] Biotech-Careers.org, "Alumni Profiles," <https://biotech-careers.org/alumni-profiles>.
- [6] InnovATEBIO, "InnovATEBIO Biotech Employers," <https://innovatebio.org/biotech-employers>.
- [7] Drupal Association, "Drupal Feeds Module," <https://www.drupal.org/project/feeds>.
- [8] CrunchBase, <https://www.crunchbase.com/search/organization.companies/b1d28ccdf520eb2ff1d8b827769406a5>.
- [9] California Life Sciences Organization, <https://www.califesciences.org/>.
- [10] "Top Biotech & Life Science Companies in Texas," <https://gov.texas.gov/uploads/files/business/BioMap.pdf>.
- [11] "NCBiotech Company Directory," <https://directory.ncbiotech.org/>.
- [12] Life Science Washington, <https://lifesciencewa.org/>.
- [13] "Biotech Employers," <https://innovatebio.org/biotech-employers>.
- [14] "Locations of US Biotech Employers," <https://www.biotech-careers.org/employer-locations-us>.
- [15] "Biotechnology Innovation Organization Membership list," <https://www.bio.org/bio-member-directory>.
- [16] BiotechGate, http://www.biotechgate.com/web/cms/index.php/covered_industry_sectors.html.
- [17] IBIS World, <https://www.ibisworld.com/global/number-of-businesses/global-biotechnology/2010/>.
- [18] "The US Bioscience Industry: Fostering Innovation and Driving America's Economy Forward," (2022), https://go.bio.org/rs/490-EHZ-999/images/TEconomy_BIO_2022_Report.pdf.
- [19] R. Carlson, "Estimating the biotech sector's contribution to the US economy," *Nat. Biotechnol.* 34(3), 247-255 (2016), <https://doi.org/10.1038/nbt.3491>.
- [20] A. Bandura, "Self-efficacy: Toward a unifying theory of behavioral change," *Psychol. Rev.* 84, 191-215 (1977).
- [21] R. W. Lent, B.L. Brown, et al., "Toward a unifying social cognitive theory of career and academic interest, choice, and performance," *J. Vocat. Behav.* 45, 79-122 (1994).
- [22] B. M. Dewsbury, C. Taylor, A. Reid, C. Viamonte, "Career Choice among First-Generation, Minority STEM College Students." *J Microbiol Biol Educ.* 20, 1-7 (2019), doi:10.1128/jmbe.v20i3.1775. (2019).
- [23] "Become Biotechnology Degrees & Careers and Biotechnology," <https://www.learnhowtobecome.org/science-technology-careers/biotechnology/#:~:text=Career%20In%2DDepth&text=Depending%20on%20their%20educational%20background,environmental%20protection%20organizations%2C%20or%20academia>.
- [24] "Biotechnology Careers: 2023 Guide to Career Paths, Options & Salary," <https://research.com>.
- [25] "Biotechnology Associates's Degree Program," https://learn.org/articles/Biotechnology_Associates_Degree_Program.html.
- [26] G. Friedman-Hunt and J. Solberg, *Careers in Biotechnology*, 3rd ed., (Chancellors Office California Community Colleges 2008).
- [27] M. Fuller, "BABEC Career Education resources," <https://www.biotech-careers.org/articles/babec-career-education-resources>.
- [28] S. Porter and K. Leung, "Classroom activities for exploring Biotech-Careers," <https://www.biotech-careers.org/articles/classroom-activities-exploring-biotech-careers>.