



Insights from Twenty Years of Biotechnology Credential Data

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Abstract: The U.S. bioeconomy has been estimated to be \$950 billion and growing [1]. Sustaining this growth requires a skilled workforce who can manufacture goods developed through biotechnology. Scaling the biotechnology workforce to the needed level requires the ability to measure its size. The National Center for Education Statistics (NCES) is the federal agency responsible for gathering education data in the U.S. Colleges that receive federal funding are mandated by law to report data every year to the NCES. Given the comprehensive nature of these data, we sought to determine whether it could be used to measure the number of certificates and degrees in biotechnology awarded by two-year colleges. An unexpected challenge was the requirement by the NCES data retrieval page for Classification of Instructional Program (CIP) codes and the inconsistent use of CIP codes by college biotechnology programs. We were able to circumvent these challenges by using data from the InnovATEBIO National Center for Biotechnology Education. InnovATEBIO data allowed us to identify two-year colleges with biotechnology programs and use those results to learn which CIP codes were being assigned. Knowing the CIP codes and their use in different states supplied the information we needed to obtain certificate and degree completion data from the NCES. These data provided insights into the changing numbers and demographics of biotech students during the past twenty years. Not only are these data important for understanding trends in biotechnology education, they are imperative for guiding the initiation, development, and sustainability of biotechnology education programs at two-year colleges.

Keywords: Biotechnology, CIP codes, credentials, workforce

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Introduction

In 1982, the FDA kick-started an exciting new industry—biotechnology—by approving Humulin®, human insulin made in bacteria, for treating human diabetes. Two years later, Alamance Community College started the first U.S. program designed to educate biotechnicians [2]. Today, the National Science Foundation's Advanced Technological Education program invests in biotechnology education by funding projects at individual colleges and the InnovATEBIO National Center for Biotechnology Education. InnovATEBIO helps colleges prepare students for the biotechnology workforce by fostering a community of two-year college programs and their faculty.

The InnovATEBIO program database

Over 136 programs in 38 states are InnovATEBIO members. Although most are based at two-year colleges, a few are at universities (11), state colleges (10), and private research institutions (Gloucester Marine Genomics Institute and The Wistar Institute). InnovATEBIO members include colleges with workforce-oriented programs outside of biotechnology, and five of the two-year colleges offer bachelor's degrees in biotechnology or biomanufacturing.



Institutions that join InnovATEBIO are asked to provide information about the kinds of programs they offer, where their students get hired, and details about dual credit partnerships and transfer options. We use these data to create a webpage for each program at InnovATEBIO.org and update these on a semi-annual basis. In this way, InnovATEBIO.org serves as an online database where program information is aggregated and distilled into reports on the state of biotechnology education at two-year colleges.

Although the InnovATEBIO database can be used to count programs and their characteristics, it cannot answer questions about the number or demographics of students who completed degrees or certificates in biotechnology. This is partly due to the challenge of conducting surveys and partly due to a lack of knowledge on the part of faculty. Faculty members know how many students complete their courses but don't always know how many complete certificates or degrees.

The National Center for Education Statistics (NCES)

During this past year, we learned how to obtain comprehensive completion data from the NCES. The NCES is the agency in the U.S. Department of Education that collects, processes, and analyzes statistical information related to education [3]. An important component of their work is the Integrated Postsecondary Education Data System (IPEDS) [4]. IPEDS is derived from 12 interrelated surveys that gather data from every college, university, technical, and vocational institution that participates in federal student financial aid programs. Data submission to IPEDS is mandatory for all colleges that participate in any financial assistance program authorized by Title IV of the Higher Education Act of 1965. Since data submission is required by law, obtaining comprehensive data without worrying about survey completion rates is possible.

Methods

Data sources and analysis

The data in this study were obtained from InnovATEBIO.org and IPEDS. For InnovATEBIO data, we focused on InnovATEBIO two-year programs that offer degrees and certificates in biotechnology or biomanufacturing [5]. Data from IPEDS were gathered from two points: the NCES College Navigator [6] and the IPEDS Custom Data Files [7]. All data sets were assembled, cleaned, and analyzed in Microsoft Excel (Microsoft, Redmond, WA).

The NCES College Navigator is a web-based search tool that provides information on tuition costs, college size, demographics, programs offered, graduation rates, and other descriptive information [5]. We used the NCES College Navigator to obtain the number of certificates and degrees completed from biotechnology programs at two-year colleges from July 1st, 2021 - June 30th, 2022. Searching College Navigator with the term "biotechnology" and applying the filters "public" and "2-year" identified 135 two-year colleges with biotechnology programs. We reviewed the program data for each one. College Navigator helped us spot information that we would have missed otherwise, such as program classifications. Three drawbacks to College Navigator were the need to look at data for each college individually, which was time intensive, the lack of demographic data for students completing specific programs, and the lack of numerical CIP codes.

Completion and demographic data from two-year college programs between 2002 and 2023 were obtained from IPEDS Custom Data Files [Supplementary Information].

Compiling a Custom Set of Biotech Programs and Obtaining Multi-Year Data on Completions

We decided to use IPEDS to learn more about the past two decades of biotechnology education. IPEDS collects data on the number of degrees or other recognized postsecondary credentials, conferred annually



during the period from July 1 to June 30, as well as data on the counts of awards conferred by award level, race/ethnicity, gender, and the 6-digit CIP codes [6].

We constructed a custom data set of colleges that offered biotechnology in the past ten years by using IPEDS Custom Data Files [6]. In this initial set, the data were limited to colleges in the U.S. that grant associate degrees and certificates. We used the two biotechnology CIP codes (Table 1) to find non-California colleges that offered associate's degrees and certificates in biotechnology. For California colleges, we used CIP code 15.0401. After downloading CSV files from 2011 through 2022, we used a pivot table in Microsoft Excel to create a list of colleges.

The next step was to create IPEDS uid files. We entered additional colleges by name for institutions outside of California and added other colleges that had offered biotechnology as part of InnovATEBIO or Bio-Link. We created a separate file for California colleges with biotech programs. Both uid files were saved and exported separately.

By uploading the uid files to IPEDS, we were able to gather data from 2002-2023 for completions by year, award level, race/ethnicity, gender, and CIP code. Data for the California colleges were downloaded separately and combined with the other results for each year. These data allowed us to look at 214 colleges per year and count the number of college programs that listed biotechnology, the number of completions per program, and student demographics.

Although this process allowed us to find most of the colleges that offered biotechnology during the past ten years, we were unable to locate data from colleges that merged with others or changed their names. We also found that one college, Gaston College, in North Carolina, reported unusually large numbers of completions for 2021 (372) and 2022 (1152). On further investigation, we learned that Gaston College awards distance education certificates for all of the North Carolina colleges that offer BioWork certificates (Russ Read, personal communication). Since our focus was on in-person programs, we removed these data before further analysis.

Results and Discussion

Colleges classify biotechnology programs in multiple ways

Our College Navigator 2021-2022 search results showed that colleges classify their biotechnology programs in two different ways (Fig. 1). Some colleges list Biotechnology under Biological and Biomedical Sciences, while others list Biotechnology under Science Technologies/Technicians. Some colleges listed Biotechnology in both places. Only a few colleges, such as Montgomery County Community College, show completions under both.



COMPLETIONS (NUMBER OF AWARDS CONFERRED) 2022-2023

Completions are the number of awards conferred by program and award level.

▼ PROGRAM	<u><12 WEEK CERTIFICATE</u>	<u>12 WEEK TO <1 YEAR CERTIFICATE</u>	<u>1 TO <2 YEAR CERTIFICATE</u>	<u>ASSOCIATE</u>
Architecture and Related Services				
City/Urban, Community, and Regional Planning	-	4	-	-
Category total	-	4	-	-
Biological and Biomedical Sciences				
Biology/Biological Sciences, General	-	-	-	22
Biotechnology	-	-	-	11
Category total	-	-	-	33
Science Technologies/Technicians				
Biology/Biotechnology Technology/Technician	-	11	-	-
Category total	-	11	-	-

Figure 1. A portion of the Programs/Majors data from Montgomery County Community College, obtained from College Navigator. In 2023, 11 MCCC students completed Biotechnology Associate degrees, and 11 students completed Biology / Biotechnology Technology / Technician certificates.

California goes its own way

A puzzling finding from the College Navigator search results was that only two of the 135 colleges were from California. This was surprising since California has 28 InnovATEBIO programs and most offer biotechnology. Even stranger, neither of the two colleges reported any completions under Biotechnology (Figure 2). By interviewing program faculty, we learned that California programs report biotechnology and biomanufacturing completions under Engineering / Engineering-related Technologies / Technicians as Biomedical Technology / Technician.

COMPLETIONS (NUMBER OF AWARDS CONFERRED) 2022-2023

Completions are the number of awards conferred by program and award level.

▼ PROGRAM	<u>UNDERGRADUATE CERTIFICATE</u>	<u>ASSOCIATE</u>	<u>BACHELOR</u>
Engineering/Engineering-related Technologies/Technicians			
Biomedical Technology/Technician	54	13	19
Science Technologies/Technicians			
Biology/Biotechnology Technology/Technician	0	0	0
Category total	0	0	0



Figure 2. A portion of the Programs/Majors data from College Navigator for MiraCosta College. The number of certificates, Associate's, and Bachelor's degrees awarded in 2022-2023 are shown under Engineering as Biomedical Technology/Technician.

Do non-California colleges report Biotechnology completions under Engineering?

We searched College Navigator with “Biomedical Technology” to see if other colleges classified biotechnology under Engineering like those in California. We found over a hundred colleges with Biomedical Technology programs and visited all of their websites. From reading the program descriptions, we learned that Biomedical Technology programs outside of California focus on instrument repair and not on biotechnology.

Finding the CIP codes and solving a mystery

During the past two years, we attended multiple presentations where researchers at the Rutgers School of Management and Labor Relations demonstrated a tool for viewing certificate and completion data from the NCES IPEDS database [8]. The Technician Graduates Data Tool is a visualization tool from The Hidden Innovation Infrastructure project at Rutgers University [9] that relies on IPEDS data. The tool is powerful but we wondered why the number of biotech completions was about half of the number we estimated. We looked at the IPEDS data to see if we could understand the reason for this discrepancy.

Table 1. CIP codes and program names

Program group	Program name	CIP code
Biology	Biotechnology	26.12
Science Technologies/Technicians	Biology/Biotechnology Technician/Technician	41.01
Engineering/Engineering-related Technologies/Technicians	Biomedical Technology/Technician	15.0401

Classification of Instructional Program (CIP) codes were developed by the NCES as a way to organize programs. A taxonomic scheme is used to assign CIP codes and organize fields of study [10,11]. Although CIP codes were created with standardization in mind, individual colleges choose which CIP code to use [12]. To obtain data from IPEDS, one must know the CIP code corresponding to a given program.

We used the NCES CIP code search page [12] to look up CIP codes corresponding to “biotechnology” and found two codes with similar definitions that matched the names in the College Navigator. We also looked up the CIP code used by the California biotech programs.

We found two CIP codes with closely related definitions that correspond to Biotechnology (Table 2). One of the codes (26.12) matches programs listed under Biology, and the other matches programs listed under Science Technicians (41.01).



Table 2. NCES CIP code definitions

CIP Code	Program Name and Definition ^a
15.0401	Biomedical Technology/Technician A program that prepares individuals to apply basic engineering principles and technical skills in support of engineers engaged in developing biological or medical systems and products. Includes instruction in instrument calibration, design and installation testing, system safety and maintenance procedures, procurement and installation procedures, and report preparation.
26.12	Biotechnology A program that focuses on the application of the biological sciences, biochemistry, and genetics to the preparation of new and enhanced agricultural, environmental, clinical, and industrial products, including the commercial exploitation of microbes, plants, and animals. Includes instruction in bioinformatics, gene identification, phylogenetics and comparative genomics, bioinorganic chemistry, immunoassaying, DNA sequencing, xenotransplantation, genetic engineering, industrial microbiology, drug and biologic development, enzyme-based production processes, patent law, biotechnology management and marketing, applicable regulations, and biotechnology ethics.
41.01	Biology Technician/Biotechnology Laboratory Technician A program that prepares individuals to apply scientific principles and technical skills in support of biologists and biotechnologists in research, industrial, and government settings. Includes instruction in fermentation technology, cell culturing, protein purification, biologic synthesis, assaying and testing, quality control, industrial microbiology, bioprocessing, chromatography and bioseparation, genetic technology, laboratory and hazardous materials safety, and computer applications

^aThe program definitions are presented verbatim from the NCES CIP database [10]

CIP code use

We looked at the use of CIP codes among biotechnology programs during the past two decades. From 2002-2008, all programs used either 26.12 (Biology) or 41.01 (Science Technologies). In 2009, all California programs switched from 41.01 to 15.0401 (Biomedical Technologies). We contacted several California faculty and administrators but were unable to determine why that switch occurred.

Overall, we can see the fraction of programs reporting completions under 26.12 (Biology) increased until 2018. This may reflect an increased emphasis on preparing students for transfer to four-year colleges and Universities. The drop after 2018 might be related to program closures.

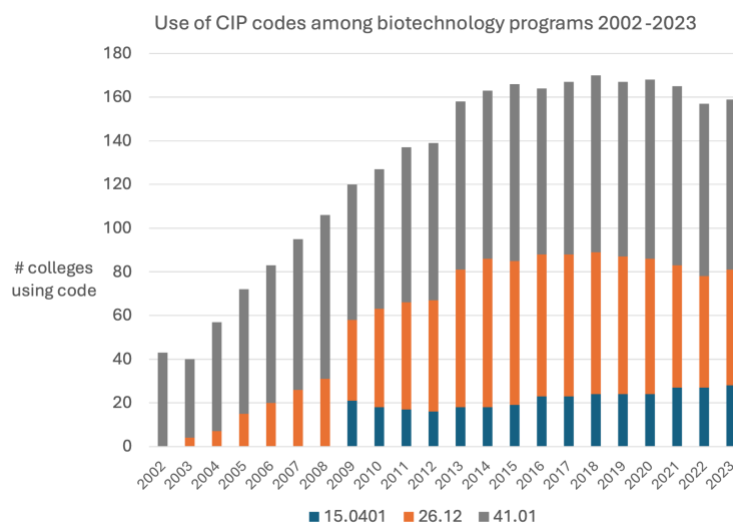




Figure 3. Use of CIP codes by college biotechnology programs. The Biology (26.12) and Science Technologies (41.01) CIP codes are used by most programs. California biotechnology programs started using CIP code 15.0401 (Biomedical Technologies) in 2009. The number of colleges using a code (shown on the Y axis) is larger than the number of college programs because many colleges report data under multiple codes.

Twenty years of student demographics - what did we learn?

The data we obtained from the NCES describes the number of completions for given CIP codes in specific years. Data were reported for a variety of certificates; some could be completed in less than 12 weeks, some within a year, some in 1-2 years, and in the case of Madison Area Technical College, some certificates were designated Post-Baccalaureate. We combined all certificate data with the exception of certificates for distance education. Data were also reported for associate's and bachelor's degrees. No distinctions were found for different kinds of associate's degrees. It should be noted that completions might not correlate directly with the number of students. If a student completed an associate's degree and a certificate in the same year, each completion would be counted.

How many credentials have been awarded by two-year biotech programs?

The number of biotechnology credential completions increased every year between 2002 and 2016, reaching a peak of 1545 completions in 2016 (Fig. 4A). In 2017, the number of completions dropped to 1413. Completion numbers rose somewhat in 2018 and 2019 and dropped during the early years of the pandemic. In 2023, total completions rose to 1528 due to an increased number of certificates.

In 2015, the number of certificates awarded surpassed the number of associate degrees for the first time (Fig. 4B, 5A, 6A). Since 2017, the number of certificates has been higher than the number of other degrees. The number of associate degrees has been dropping since 2016.

Five two-year colleges offered bachelor's degrees in biotechnology during the 2002-2022 time period, and the number of completions is rising. The first college to offer a Bachelor's degree in biotechnology was Santa Fe College in Florida in 2016. Four California colleges (Mira Costa College, Solano College, Los Angeles Mission College, and Solano College) began this practice shortly afterward. Moorpark College has recently started offering bachelor's degrees, and Los Angeles Pierce College is working toward offering them. Although the California bachelor's degree programs are in biomanufacturing, they use the same CIP code (15.0401) as other California programs.

A.

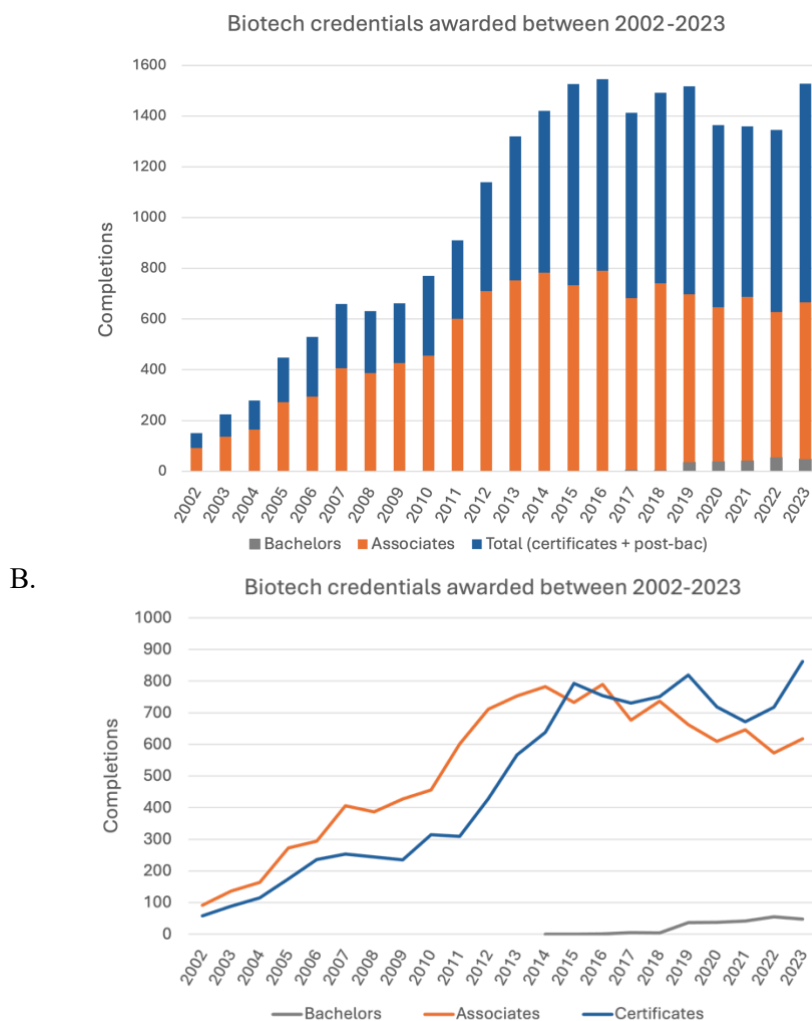


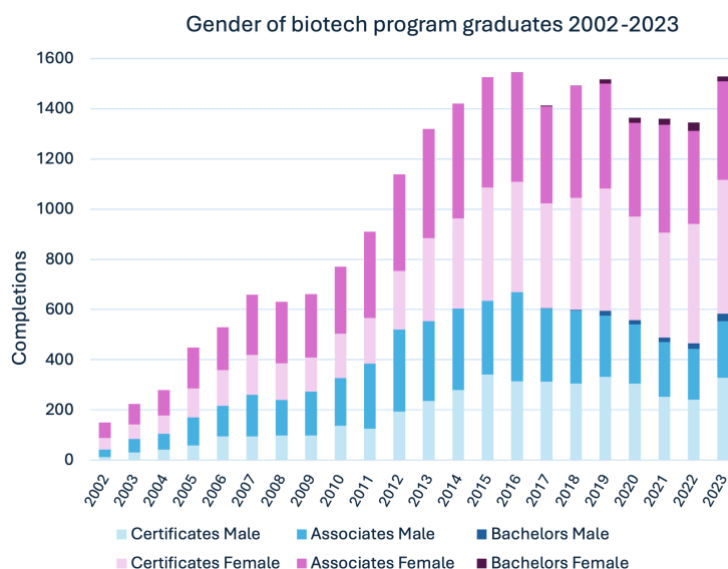
Figure 4. Biotechnology completions between 2002-2023. A. Total numbers of Certificates, Associate's degrees, and Bachelor's degrees, completed between 2002-2023. B. Bachelor's degrees, Associate's degrees and certificates are plotted separately.

When it comes to biotechnology, women dominate

Since 2002, the fraction of students completing certificates has increased for both women and men (Fig. 5A and B). Between 2002 and 2023, the fraction of women completing biotechnology degrees ranged between 72 and 54%, with an average of 64% (Fig. 5B). A larger number of completions were seen in 2023 due to increases in both men and women completing certificates.



A.



B.

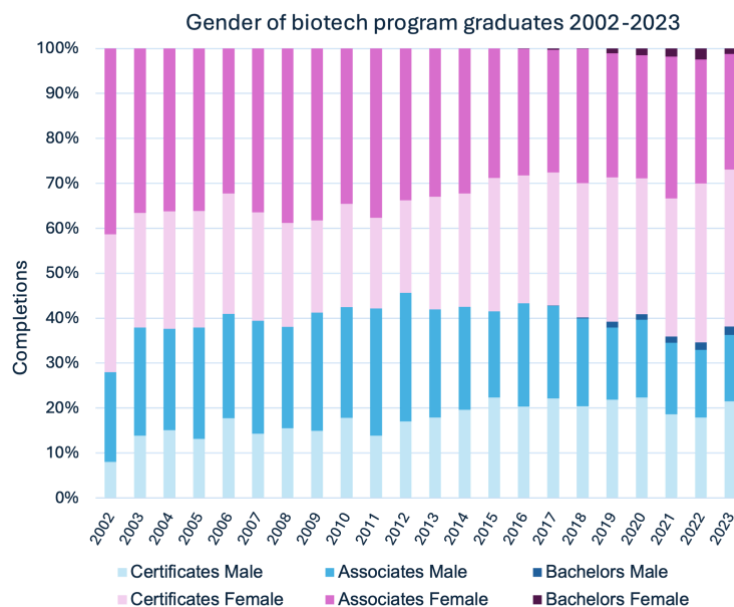


Figure 5. Biotechnology completions by gender between 2002-2023. A. Total completions by gender and credential type. B. Completions by gender, percent, and credential type.

Biotechnology programs are increasing in diversity

We looked at NCES race/ethnicity completion data to learn about the demographics of students completing biotechnology credentials. Overall, the population of students completing biotech credentials has been getting more diverse, with the fraction of white students trending downward since 2009 (Fig. 6). During that same period, the fraction of Asian and Hispanic or Latino students has been growing while the fraction of Black or African American students has remained around 10% (Fig. 6B).



One thing we noted in analyzing the race/ethnicity data was that the total number of completions from these groups was slightly lower than the total number of completions overall. We were unable to find an explanation for this discrepancy.

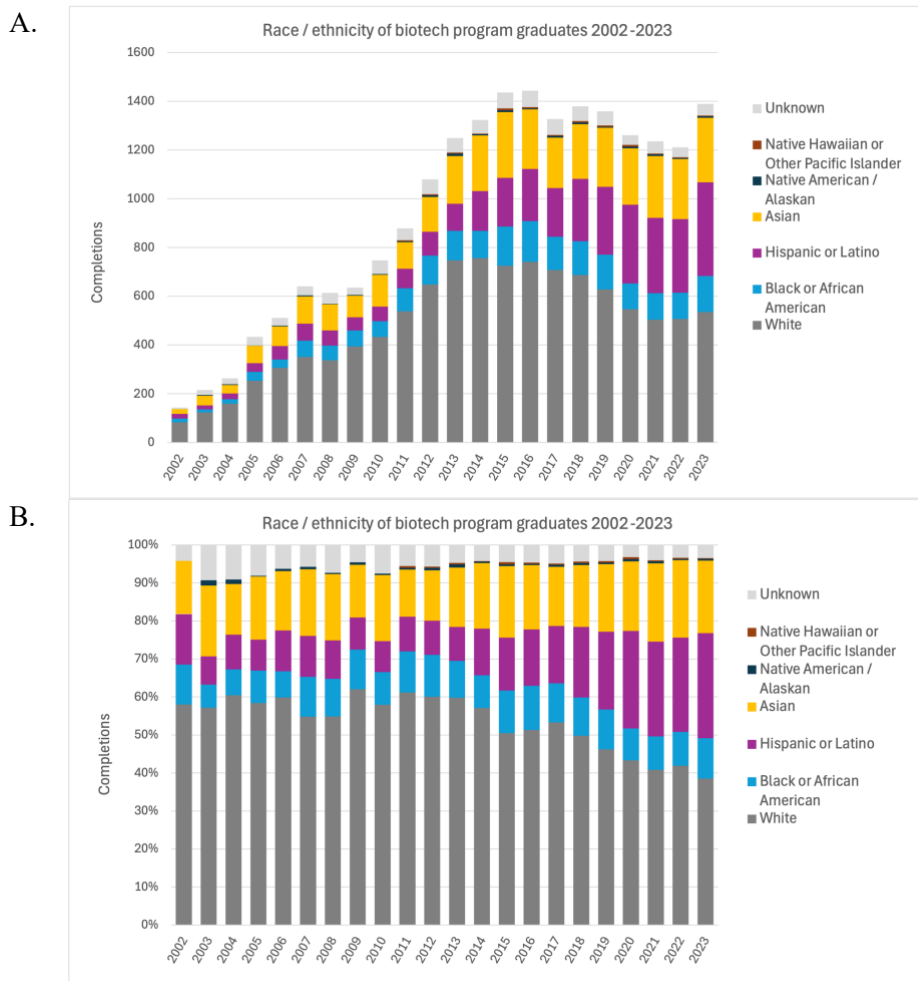


Figure 6. Biotechnology completions by race/ethnicity. A. Total completions by race/ethnicity. B. Percent of completions by race/ethnicity.

The number of biotechnology programs is dropping

We counted the number of U.S. colleges that reported completions under both biotech CIP codes (26.12 and 41.01) and California colleges using the 15.0401 CIP code. These data showed that the number of programs increased from 35 in 2002 to a peak of 155 in 2018 and an endpoint of 138 in 2023 (Fig. 7). We have reason to think that the later numbers are an overestimate. Notably, 33-38 programs reported zero completions between 2017-2023. New programs are expected to report zero graduates since it takes time to recruit students and grow. These programs, however, were well established. The lack of graduates in these cases suggests those programs may be close to ending.

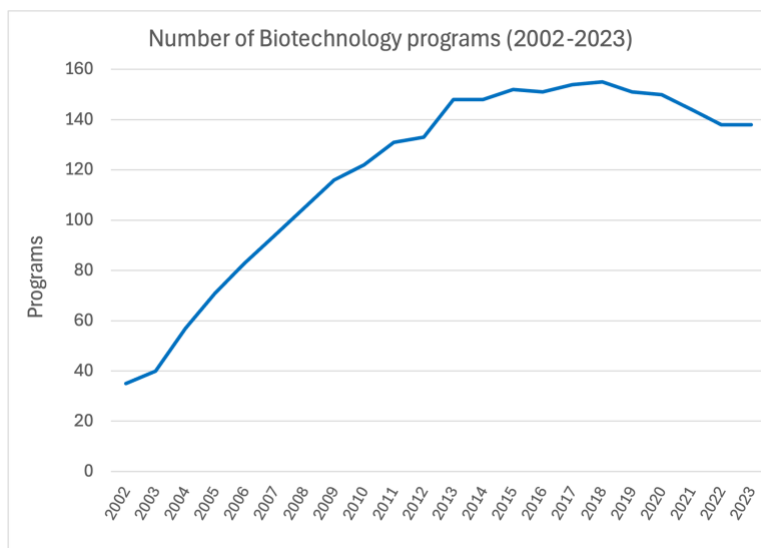


Figure 7. Biotechnology completions at two-year colleges between 2002-2023.

Some biotechnology programs get larger and smaller programs disappear

We assigned programs to bins based on the number of total completions and looked at the number of programs in each bin. These data show an increased number of associate and bachelor degrees and certificates completed between 2002 and 2018, with a decrease after 2018. In 2023, 14% of the programs had over 20 completions, and seven programs had over 50. MiraCosta College reported the highest number of completions (158 in 2020 and 134 in 2019) (See supplementary data, figures 8 and 9).

Notably, the number of programs reporting zero completions also grew. Since 2017, 20-28% of the programs have reported zero graduates.

What can we say about InnovATEBIO programs?

We began this project, in part, to identify and better understand the trends impacting biotechnology programs at two-year colleges that are members of InnovATEBIO. Feedback from our community has indicated that biotech programs at two-year colleges are facing difficult times. Low enrollments, the pandemic, and faculty retirements have contributed to closing at least 20 programs since InnovATEBIO began in the Fall of 2019. Several others are struggling.

In 2022, the NCES College Navigator data provided a list of 138 colleges that reported completion data for biotech-related CIP codes or the engineering CIP code in the case of California. On reviewing this list, we found that 35 of the programs had zero graduates. By visiting the college websites, we learned that many of the programs with zero graduates, plus a few others with low numbers, were closed. Of the remaining programs, 84% belong to InnovATEBIO (16 did not belong, 86 were InnovATEBIO members).

We further analyzed the InnovATEBIO programs to determine the number of completions for each program. After removing two programs that closed and new programs that had not yet graduated any students, we had a list of 80 programs. We gathered 2023 completion data for these programs by looking up the results for each college in College Navigator.

This set of 80 InnovATEBIO programs had 1175 total completions in 2022 and 1271 in 2023, indicating some growth. As noted earlier, these programs tend to be small. The median number of completions was



7.5 in 2022 and 9 in 2023. Only 17 programs had over 20 completions in 2022 and 2023, and 75% of them had fewer than 20 graduates (Supplemental data Fig. 9A and B).

Conclusion

Information about the number of program graduates is important for evaluating the health of community college biotechnology education as a whole and for guiding InnovATEBIO activities. In future analyses, we are interested in identifying the factors that make biotech programs successful. To do this, we will look at InnovATEBIO programs that consistently show large numbers of completions, characterize the types of completions (short-term certificates, long-term certificates, associates, and bachelor degrees), and use information from the InnovATEBIO database to help identify correlations between program characteristics, such as dual credit options, or bachelor's degrees, and the numbers of completions.

It should be noted that this report focuses on completions. Not all students who take biotechnology courses complete certificates or degrees. Some take one or two courses and find jobs. Others might transfer without completing a degree or certificate.

By analyzing biotech-related completion data from the NCES, we learned how biotechnology programs report their data to IPEDS and which CIP codes are used. This is important for future analyses. The data show that biotechnology completions have grown over the past twenty years but began trending downward in 2016. In terms of demographics, women make up a large fraction of biotechnology students, and the number of biotechnology graduates is becoming more diverse. Many biotechnology programs are small, but at least 17 programs had over 20 graduates in 2022 and 2023. By studying these programs, we hope to identify practices that can benefit the other biotechnology programs and technical programs in the ATE community as a whole.

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Disclosures. The authors declare no conflicts of interest.

Supplemental Materials. Please see (link to be created by designers)

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