# PREP-aring is worth it: Success of the Case Western Reserve University Post-baccalaureate Research Education Program and its Scholars

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## Abstract

The Post-baccalaureate Research Education Program (PREP), established by the National Institute of General Medical Sciences (NIGMS) at the National Institutes of Health in 2000, was a research-intense, one-year training program for recent college graduates from backgrounds uncommon in science who intended to matriculate with a PhD or MD/PhD program in preparation for an eventual career in biomedical research. Case Western Reserve University had an NIGMS-supported PREP (CasePREP) from 2007 to 2025, the year NIGMS terminated the PREP funding mechanism. A major goal of CasePREP was to prepare post-baccalaureate trainees (termed Scholars) for graduate school, and major metrics of success were measured as Scholars who a) matriculated in and b) completed PhD or MD/PhD programs. A major goal of NIGMS-supported PREPs was the retention of these scientists in the biomedical research workforce. We report here the extent that CasePREP met program goals as well as the economic and scientific impact NIGMS-supported PREP has had for a variety of stakeholders. Data from 18 CasePREP cohorts included self-reported (surveys, interviews, questionnaires) and public data (websites, PubMed, NIH Reporter). Descriptive statistics and large language models were used to describe the major outcomes related to program goals and a new resilience course as well as Scholar productivity and contribution to science. Between 2007 and 2025, CasePREP was awarded $5.6 million USD and trained 108 Scholars. Most (89%) Scholars resided outside of Ohio prior to the start of CasePREP, with 38.89% from Puerto Rico. Almost all (98%) Scholars completed the one-year program in Cleveland, Ohio, and of those, 83% entered a PhD or MD/PhD program. As of September 2025, 46 Scholars have completed a PhD program, two Scholars have completed an MD/PhD program, and 27 are still in training. The attrition rate for CasePREP Scholars in graduate school is currently 14.77%, much lower than the attrition rates of national PhD

programs. Most CasePREP Scholars (69.44%) are co-authors on one or more published manuscripts, and these 406 published works have garnered 14,261 total citations, with an average 35.04 citations per publication. Termination of PREP represents a five-year loss of ~$2.7 million USD to CasePREP, a budget that would have trained an additional 30 Scholars. CasePREP was a great success as measured by its major outcomes. CasePREP Scholars have persisted in science and have made substantial contributions to the scientific workforce and enterprise. PREPs in general provided a crucial bridge for research talents who had little prior research opportunities to realize their potential and career goals. NIGMS termination of PREP support has negative economic consequences and endangers an important pathway to a career in science for Americans who would not otherwise have similar opportunities.

## Introduction

The Post-baccalaureate Research Education Program (PREP) was established in 2000 by the National Institute of General Medical Sciences (NIGMS) at the National Institutes of Health with the funding announcement PAR-00-139 and first awards in 2001 (Hall, Mann, and Bender 2015; McGee, Saran, and Krulwich 2012). The intention and goals of the program targeted well-documented scientific workforce challenges (2024) by providing research and professional development opportunities to recent college graduates from backgrounds not common in science who were interested in pursuing a doctoral degree in biomedical research fields of study. The program was initially intended for specific US demographic groups but had since expanded to include uncommon backgrounds based on geography (e.g., rural), economic resources, disabilities, and other factors or situations that negatively impacted academic performance and/or limited research opportunities necessary for successful matriculation in a PhD-granting program in biomedical research.

Case Western Reserve University (CWRU) School of Medicine was awarded PREP in 2006 under PAR-03-140 and has been ongoing through 2025 under PAR-17-051. CWRU ("Case") PREP has completed 18 cohorts of postbaccalaureates or "Scholars" and is one of the longest running NIGMS-support PREPs in the United States. With almost 20 years of data for 108 CasePREP Scholars, we describe here the outcomes of the program as well as the economic and scientific impact CasePREP has had on the state of Ohio and the international research community.

## Methods and Materials

Outcomes data were collected from Scholars at three stages: 1) during the application process, 2) during CasePREP, and 3) after CasePREP. Required application data included basic demographic data, permanent and temporary contact information, self-reported eligibility for CasePREP, undergraduate institution, grade point average, degree, personal statement, statement of interest, and letters of recommendation. Optional was self-reported standardized test scores (e.g., GRE, MCAT, SAT, ACT). Data collected during CasePREP included pre- and post-PREP surveys, courses taken during PREP, grades, seminars attended, laboratory rotations, research summaries, oral and poster presentations given, conferences attended, awards, publications, applications to graduate programs and decisions, and immediate post-PREP position taken. Surveys were self-administered; other data were self-reported in a custom database. Post-PREP data were collected in a variety of ways including personal contact (via email, phone, or LinkedIn message), public-facing websites and social media, PubMed, and NIH Reporter. Where indicated, large language models were used as assistive tools for text processing and exploratory categorization; all interpretations and conclusions were determined by the authors.

Economic impact estimates were based on actual CasePREP salaries committed at the start of each PREP assuming salary payment followed the calendar year (as opposed to the academic year). Adjusted gross incomes were calculated using year-specific federal standard deductions for a single filer for tax years 2007-2024, and federal taxes paid assumed a tax rate of 15%. Historic standard deductions and social security and Medicare withholding rates (from irs.gov) were applied to the committed salaries, and Ohio sales tax rates were applied to estimated take home salaries (estimated social security, Medicare, and federal taxes subtracted from committed salaries).

Return of investment was calculated using the standard equation

$$(\text{Net Program Benefits} - \text{Program Costs}) / (\text{Program Costs}) \times 100,$$

where “program costs” were the NIH per Scholar funds committed to CWRU during the entirely of the program ($5,623,773/108 Scholars = $52,072/Scholar) for the 88 CasePREP Scholars who enrolled in a PhD or MD/PhD program. To calculate “net program benefits”, we defined a benefit of PREP as lower attrition among the 88 Scholars who enrolled in graduate school compared with a hypothetical class of 88 first-year graduate students who did not participate in the post-baccalaureate program. To define the “net program benefits” variable, we assumed graduate students were supported by NIH at $50,000/trainee, which closely represents the total per year stipend, tuition, and research related costs currently allowed for the NIH Predoctoral Individual National Research Service Award (NRSA) and NIH Ruth L. Kirschstein NRSA Institutional Research Training Grant (Health 2025h).  We estimated NIH support for graduate students who eventually left their programs without a PhD after 1) two years and 2) three years, the periods of training that align with candidacy after comprehensive or qualifying exams, the completion of formal coursework, and the commitment to independent dissertation research. Given attrition rates vary by field of study, program, and year (King 2008), we assumed four attrition rates (25%, 45%, 50%, and 55%) compared with an assumed 15% for CasePREP (14.77% as of September 2025). All economic estimates are conservative and intended to illustrate order-of-magnitude impacts rather than precise accounting.

Carnegie Classifications of Institutions of Higher Education were used to characterize Scholars’ final degree granting undergraduate institutions using their “institutional characteristics” and “student access and earnings” columns. Carnegie Classifications of Institutions of Higher Education were also used to classify institutions enrolled by Scholars for PhD or MD/PhD programs. Carnegie Classifications of Institutions of Higher Education does not provide “student access and earnings” for Schools of Medicine; for these institutions, we used the 2025 US News & World Reports Medical School Research Rankings and assumed all tier 1 medical schools, medical colleges, and Schools of Medicine would be considered "higher earnings". For medical schools not participating in US News & World Reports rankings (e.g., Johns Hopkins University School of Medicine; University of Michigan Medical School; University of Washington), we assumed these would have been classified as tier 1.

Salaries were estimated for CasePREP Scholar alumni who had a post-terminal degree position as of December 2024. Actual salaries were collected from public sources, and when not available, estimates were collected from public sources (Glassdoor, Salary.com) based on the Scholar's employer and position. When lower and upper salaries were available, the average of the two was used to represent the Scholar's estimated salary.

CasePREP Scholar publications were collected manually using Scholar names and PubMed. PubMed IDs were recorded for publications that listed the Scholar as a co-author. Publication titles associated with the PubMed IDs were extracted from PubMed and parsed using CRAN packages 'easyPubMed' and 'wordcloud' in R scripts generated using Anthropic's Claude Sonnet 4.5 and subsequently reviewed and modified by the authors. Data were plotted using ggplot2 in R 4.5.1. Citation and publication influence metrics were based on iCite queries using CasePREP Scholar-associated PubMed IDs as inputs. iCite also provided "cited by" PubMed IDs, which were used to calculate first and second-generation citation metrics through iCite and requested Claude Sonnet 4.5 analyses.

These outcomes data were collected for evaluation of the program as generally required by PAR-22-220 and associated Notice of Funding Opportunities. The CWRU Institutional Review Board (IRB) determined CasePREP (STUDY20240922) to be non-human subjects research.

## Overview of CasePREP

NIGMS-supported PREP is generally a one-year, non-degree granting post-baccalaureate training period designed to prepare Scholars for graduate school and careers in science through professional development, course work, and research. Similar to other PREPs, CasePREP provided Scholars with a core experience in the laboratory or research group as a scientific apprentice equivalent to a first-year graduate student (**Table 1**). Scholars were matched with accomplished investigators and their laboratory or research staff to immerse them in a mentored, research-intensive experience. CasePREP Scholars were expected to take a graduate-level course each semester of the program as well as On Being a Professional Scientist: the Responsible Conduct of Research, a graduate-level course required in the Spring semester. Professional development throughout the academic year included developing and delivering oral presentations (e.g., research updates; journal club), developing and submitting conference abstracts, and presenting scientific posters at local and national conferences. The Scholars also developed Individual Development Plans, wrote personal and research statements for graduate school applications, and drafted their curriculum vitae. In the spring semester, Scholars interviewed for graduate schools after a series of mock interviews with CWRU School of Medicine faculty. Scholars also drafted an NIH-style specific aims page and participated in a mock NIH study section (**Table 1**). Throughout the program, Scholars received oral and written feedback from the program directors, program administrator, and research mentors.

## Addition of resilience and wellness resources

The COVID-19 pandemic and associated isolation and stress revealed a general need for additional mental health support. Through a one-year supplement from NIGMS, CasePREP offered the class of 2023-2024 1) access to counseling services through CWRU’s University

Health and Counseling Services and 2) a new wellness and resilience course. In the Spring 2024 semester, we implemented the new wellness and resilience curriculum designed around the existing National Institute of Health (NIH) Becoming a Resilient Scientist Series, offered by the Office of Intramural Training & Education (OITE) (Han 2025). This series, consisting of five webinars and discussion groups, was originally developed by NIH in 2020 in response to increased demand for these seminars during the COVID-19 pandemic (Han 2025). The series and discussions covered the following topics**:** Introduction to Resilience and Wellness (Unit 1); Exploring our Self-Talk: Cognitive Distortions and Imposter Fears (Unit 2); Self-Advocacy and Assertiveness for Scientists (Unit 3); Developing Feedback Resilience (Unit 4); and Managing Up to Maximize Mentoring Relationships (Unit 5). All webinars, each two hours in length, are available on-demand through YouTube. Also available were accompanying workbooks designed to emphasize video content and to structure the weekly discussions after videos are viewed. CasePREP's version leveraged the Fall 2022 YouTube videos and associated Fall 2023 workbook materials as weekly assignments. The units were split into two, and the resulting 13 weekly small group discussions were led by an early career trained facilitator whose education and training background mirrored many Scholars' backgrounds ("near-peer"). Neither the CasePREP co-directors nor the CasePREP administrator attended these small group discussions, and all discussions were understood by the Scholars and the facilitator to be confidential.

To evaluate the effectiveness and perceived value of the added resilience and wellbeing resources, a pre- and post-course survey was administered via Google Forms to the CasePREP Scholar cohort using a six-item Brief Resilience Scale (BRS) (Smith et al. 2008) available through the PhenX Toolkit (Hamilton et al. 2011) (protocol ID 251401). The post-course survey also included the open-ended question "Do you have any comments on the resilience in science class or general access to resources related to resiliency during PREP?" In addition to the six-item survey, the facilitator held a group exit interview discussion to ask the following questions: Were you satisfied with the content of the NIH recorded series? What did you think of the format of this semester-long course? Will you use what you learned in graduate school and other personal or professional settings? What, if anything, do you plan to use from this course? What are or might be the factors or barriers to applying what you learned? How can this course be improved? What other resources could be made available related to resilience tools needed to study and work in high-knowledge environments? What part of this course was most useful or valuable to you? The facilitator recorded the discussion to transcribe the conversations, redacting identifying information. The recording was deleted after the transcription was completed. Claude Sonnet 4.5 was used to assist with preliminary categorization of text by sentiment, after which themes were reviewed, refined, and interpreted by the authors. From these data, the CasePREP resilience series was offered for the entire 2024-2025 academic year, and discussion groups met every other week instead of weekly.

## Results

CasePREP appointed 108 Scholars between the 2007-2008 and 2024-2025 academic cycles. Approximately one-third (33%) were male, and all were US citizens or permanent US residents not more than 36 months from when their bachelor's degree was conferred. At the time of application, Scholars resided in 25 states, Puerto Rico, and the US Virgin Islands, with the majority residing in Puerto Rico (38.89%), Ohio (10.19%), California (9.26%), and New York (5.56%; **Figure 1**).

CasePREP Scholars earned four-year Baccalaureate degrees from 58 US institutions in 21 states, Puerto Rico, and the US Virgin Islands. According to the Carnegie Classifications of

Institutions of Higher Education, the majority of the institutions are classified as “mixed Undergraduate/Graduate-Doctorate” (43.52%) and “mixed baccalaureate” (17.59%), where “mixed” is defined as <50% of degrees are awarded in any one focus area (Teaching 2025) (**Figure 2**). Of the 58 institutions, most were classified as having research activities: “Research 1: Very High Spending and Doctorate Production” (30.56%), “Research 2: High Spending and Doctorate Production” (36.11%); and institutions spending at least 2.5 million on research & development on average in a single year but not classified as Research 1 or 2 (6.48%) (Education 2025). A quarter (26.85%) of CasePREP Scholars’ baccalaureate institutions do not have substantial research activity.

Almost all (98.15%) CasePREP Scholars completed the post-baccalaureate program. Of those who completed CasePREP, the majority (83%) matriculated with a PhD or MD/PhD program within one to two years of completing the post-baccalaureate program. CasePREP Scholars matriculated with PhD and MD/PhD programs across 33 US institutions, including CWRU School of Medicine (30.7%) and the University of Michigan Medical School (10.2%). Of the 88 that entered a PhD or MD/PhD program, at least 19 (21.59%) received independent, external fellowships or supplements for their training, including 12 NIH National Research Service Award (NRSA) F31s; one NIH NRSA F30; one NIH training supplement to an NIH U01; two National Science Foundation (NSF) Graduate Research Fellowship Program (GRFP) fellowships; and three Howard Hughes Medical Institute (HHMI) Gilliam Fellowships. Another two trainees were awarded grants to transition from predoctoral studies to post-doctoral studies (NIH F00/K99). Three CasePREP alumni with PhDs are now Burroughs Wellcome Fund (BWF) Postdoctoral Diversity Enrichment Program (PDEP) awardees (with one also designated a Revson Scholar).

### *CasePREP Resilience Cohort*

The counseling services and resilience course (see Methods and Materials) were made available with the 2023-2024 cohort of six Scholars. The pre- and post-course survey suggests the majority of Scholars had improved or unchanged resiliency for five of the six items on the brief resilience scale (**Figure 3**). The post-course survey open-ended question was answered by the majority and was generally positive ("It was a time to take a breather during the day and it helped me feel more relaxed in the afternoon of that day."; "I enjoyed being able to connect with my peers and bond over shared concerns, it made me feel less alone in my struggles."; "Learning about different resources related to resiliency during PREP and having the opportunity to talk about our experiences/struggles in a safe environment was very helpful. I think having this class made me learn a lot about myself and understand how I can better manage different situations in my life in a healthier way."). Six themes emerged from the guided group exit interview: course content, course structure, application of course content in life as a graduate student, support, relevance, and barriers to implementation (**Table 2**). The negative feedback and suggestions included comments related to the course itself and general comments related to support outside of class (**Table 2**).

### *CasePREP Scholar Contributions to Science*

Of the 108 CasePREP Scholars, 75 (69.44%) are co-authors on a manuscript published in a peer-reviewed journal indexed in PubMed. As of September 2025, there are 407 unique PubMed IDs associated with CasePREP Scholars; of these, 15 PubMed IDs are associated with more than one CasePREP Scholar reflecting CWRU mentors and research groups who trained both CasePREP Scholars and alumni as graduate students. Based on manuscript titles, the most common research topics published by CasePREP Scholars included cancer research (n=57 mentions of "cancer").

Other areas of research and fields of study were also represented, including immunology research (n=26 mentions of “immune” or “immunity”) and COVID-19 research (n=17 mentions of “covid”); research using model organisms (n=18 mentions of “mice” or “rats”); and nanotechnology research (n=22 mentions of “nanoparticles(s)”), to name a few (**Figure 4**). The number of publications per year peaked in 2021 with 58, possible reflecting the consequences of the COVID-19 pandemic stay-at-home mandates in 2020 that reduced laboratory hours and increased work-at-home hours conducive to writing. In general, the number of publications has increased over the course of CasePREP (**Figure 5**), both reflective of the increasing cumulative number of Scholars in the long-running CWRU post-baccalaureate program but also the retention of CasePREP alumni in graduate school and in the scientific workforce afterward.

To characterize the impact of CasePREP Scholar research, we queried iCite for number of citations, relative citation ratios, and PubMed IDs of citing publications. Of the 407 CasePREP Scholar publications, 406 were available in iCite (Hutchins et al. 2016). As of September 2025, the Scholars’ published work has garnered 14,261 total citations, with an average 35.04 citations per publication (standard error of the mean = 3.19). The Scholars’ collective body of work has a weighted citation ratio of 742.59. The most highly cited Scholar-associated publication to date (Scott et al. 2019) has a relative citation ratio of 24.36, indicating this paper has received 24 times the citations per compared with the median NIH-funded publication. The most highly cited Scholar-associated publication is the most influential CasePREP Scholar-associated publication in a cascade of two generations: it is directly linked to 806 citations (1st generation), and those citations are linked to 43,343 citations (2nd generation). Collectively, the 406 CasePREP Scholar-associated publications are associated with 240,367 2nd generation citations, and conservate estimates suggest approximately 15.6 million citations are linked by the 4th generation.

### ***Economic Impact on the State of Ohio***

Over the course of 18 years, the NIH awarded a total of $5,623,773 to CWRU to administer CasePREP. Each year of the award, the NIH training grant supported a proportion of the director's (faculty's) effort (15% total 2007-2018; 10% total 2019-2024), a proportion of the program coordinator's (staff's) effort (50%), and the effort for each CasePREP Scholar (100%). In total, the 18-year NIH award supported the equivalent of 119.45 full-time positions at CWRU.

CasePREP was an in-person post-baccalaureate program held on the CWRU campus located in Cleveland, Ohio in Cuyahoga County. The majority of CasePREP Scholars (87.04%) earned their Bachelor's degree from a university located outside of the state of Ohio; consequently, the majority of Scholars became new, tax-paying Ohio residents the year that they participated in CasePREP. Ohio has both a state income tax and a sales tax, the latter of which is applied to apparel, electronics and furniture. The NIH-supported CasePREP salary for Scholars ranged from $21,000 USD (2007-2011) to $27,200 USD (2012-2024). CWRU SOM subsidized CasePREP salaries by $100 USD beginning in 2019, and the subsidy was substantially increased in 2023 ($5,800 USD) and 2024 ($7,800 USD) to closer match national post-baccalaureate salary averages. CasePREP adjustable gross incomes were almost always below the Ohio tax bracket threshold that trigger state tax payment. The sales tax rate for Cleveland, to which all CasePREP Scholars, faculty, and staff were subject, ranged from 7.75% to 8% over the course of CasePREP. Assuming the post-baccalaureate trainees spent 30% of their take home pay on taxable goods, CasePREP Scholars paid an estimated $62,263 in Ohio sales tax over the course of the program. Of the approximately $3,167,600 USD earned in total salary over the 18 years of the program, CasePREP Scholars paid an estimated $189,767 USD and $45,930 USD in social security and Medicare withholdings, respectively, and an estimated $319,388 USD in federal taxes. The majority of CasePREP Scholar total salary (~83%), an estimated $2,612,515, was take home pay spent in Ohio on food, housing, sales taxable goods, and other services.

### ***Return of Investment***

Over the course of CasePREP, CWRU was awarded a total of $5,623,773 USD ($5,215,025 direct costs and $408,708 indirect costs) from NIH spanning the parent grant, three renewals, and two supplements. The average NIH investment for 108 CasePREP Scholars on a per Scholar basis was $52,072. Major measures of CasePREP success include the proportion of Scholars who enter graduate programs 1) remain in the programs and 2) complete the programs with a PhD or MD/PhD. As of September 2025, 88 of the 106 (83.02%) Scholars who completed CasePREP entered a PhD or MD/PhD program. One recent CasePREP Scholar deferred enrollment to a PhD program and is expected to matriculate the 2026-2027 academic cycle. Of the Scholars who entered PhD or MD/PhD programs, the majority (85.23%) are either current trainees (n=27) or have earned a PhD (n=43), MS/PhD (n=2), MBA/PhD (n=1), or an MD/PhD (n=2) as their terminal degree. The average time-to-degree for the 48 CasePREP Scholars was 6.17 years: 6.12 (standard deviation = 1.26; median = 6) years for PhDs and 6.75 (standard deviation = 2.06; median = 6.5) years for dual degrees.

The observed low graduate school attrition rate among CasePREP Scholars (14.77%) suggests early investment in this post-baccalaureate program better ensures that future NIH investment in graduate training results in a trained scientist (e.g., completion of PhD). To quantify this, we first estimated hypothetical NIH funds committed to CasePREP Scholars lost to attrition compared with a hypothetical first-year graduate student cohort of 88 trainees lost to attrition at rates reported in the literature (**Figure 6**). Compared with CasePREP Scholars, NIH investment lost to attrition is 1.69 – 3.72 times higher among typical graduate students, with estimated losses ranging from $2.2 million to $7.26 million USD for a cohort of 88 trainees (**Figure 6**). Return of investment estimates (see Methods and Materials) indicate that NIH costs per CasePREP Scholar who enter graduate school save NIH investments lost to attrition when PhD program attrition rates are at least 50% (**Figure 7**).

### *Social Mobility and Earning Potential*

CasePREP, like all NIGM-supported PREPs at the time, solicited applications from recent college graduates with backgrounds not common in science, including those who were economically disadvantaged. Data indicate that postsecondary education increases wages and promotes intergenerational mobility for those individuals with those credentials or degrees compared with those without postsecondary degrees (Autor 2014; Kwakye and Oliver 2022), and that the effects are especially pronounced for students from the lowest income quartile (Kwakye and Oliver 2022). CasePREP Scholars already have a postsecondary education degree (Bachelor’s) but are seeking the highest level of education with a doctoral degree. For the CasePREP Scholars who entered a PhD or MD/PhD program, we used the Carnegie Classification of Institutions of Higher Education “student access and earnings” to quantify evidence of social mobility and increased earning potential after completion of PREP. Of the 88 CasePREP Scholars who enrolled in a PhD or MD/PhD program, one enrolled in a PhD program at a research institution not included in the Carnegie Classification of Institutions of Higher Learning and one enrolled in a medical college neither included in the Carnegie Classification of Institutions of Higher Learning nor ranked by US News & World Reports. Of the remaining 86 Scholars, 20 (23.3%) earned a Bachelor’s degree with from an institution classified as medium to lower earnings potential and enrolled in a PhD granting program at a university or School of Medicine classified as higher earnings potential.

To characterize realized earning potential, we first considered all CasePREP Scholars who earned a PhD and had a known salaried position as of December 2024 (n=40; **Figure 8**). Of these CasePREP alumni, half held positions in industry and half in academics with an average 4.30 and 3.55 years since completion of their PhD, respectively. Among those with industry positions, the average estimated salary in 2024 was \$152,028 (standard deviation = \$52,403; median = \$157,484), ranging from an estimated \$74,705 to \$238,500. Compared with CasePREP alumni with PhDs in industry, those in academia had a lower estimated average 2024 salary of \$74,174 (standard deviation = \$17,465; median = \$71,880), consistent with instructor or junior faculty positions and post-doctoral training.

In addition to working CasePREP alumni who earned PhDs, 19 CasePREP Scholars earned other terminal degrees and held salaried positions as of December 2024. These working alumni included those who earned 1) a Master's (n=6) degree and held positions in industry, 2) a Doctor of Medicine (MD) or Doctor of Osteopathic Medicine (OD) degree (n=6), 3) a dual medical (MD/PhD, MD/JD/MS, or MD/MPH) degree (n=5), 4) a dual PharmD/MS degree, and 5) an MBA. An additional four CasePREP Scholars were known to have entered the workforce with a Bachelor's degree. The average estimated salary for CasePREP alumni working with a Bachelor's degree (estimated average of \$81,295) is similar to the average 2024 earnings reported by the US Bureau of Labor Statistics for all working Bachelor's degree holders >25 years of age (\$80,236) (Statistics 2025). The salary averages for other terminal degrees are higher than average salary for Bachelor's degree holders, but these differences are not statistically significant in pairwise comparisons ($p>0.05$; t-tests) reflecting the wide range of salaries within each terminal degree group and the relatively small sample sizes.

## Discussion

CasePREP, with 108 Scholars and $5.6 million in federal funding over the course of nearly 20 years, has made a substantial impact on the local Cleveland, Ohio economy and the international scientific community. CasePREP alumni include 44 PhDs; 1 MS, PhD; 1 MBA, PhD; 2 MD/PhDs; 6 MDs; 1 DO; 1 MS, JD, MD; 1 MPH, MD; 1 MS, PharmD; 1 MBA; and 9 Master's (**Figure 9**). More than two dozen alumni are still in training. Post-PREP follow-up indicates that the majority of Scholars, regardless of their terminal degree, entered and have remained in the scientific workforce. For many Scholars, CasePREP made an impactful contribution to their earning potential. Of the Scholars who have published, their collective body of work has been highly impactful reflected in the number of direct and cascading citations in the literature.

The data presented here were collected primarily for program evaluation purposes; consequently, there are several limitations. First and foremost, CasePREP alumni were not directly surveyed for information such as awards or fellowships, dates of thesis defense, or current salaries. These data were primarily scraped from public-facing LinkedIn and websites or identified in NIH Reporter and NSF GFRP Fellowship database queries. When not available, data were inferred or extrapolated based on reasonable assumptions as detailed in Methods and Materials. While care was taken to provide reasonable point estimates, there may be sizable differences between the estimated and the actual. Also, data available in LinkedIn may not be up-to-date or as granular as desired. For example, the CasePREP average time-to-PhD of 6.12 years is likely closer to the national average (~5.5 years) given 1) month degree was conferred is not recorded, only year, and 2) thesis defense date was not recorded.

Evaluation of the added resilience course and wellness resources was also limited. The pre- and post-survey for the resilience course was only administered to a single CasePREP Scholar cohort, and the course was only available to two cohorts. While limited in sample size, the data suggest the course was generally well-received and valued. The Scholars appreciated the opportunity to spend time together and with a near peer to discuss non-academic topics important to them at that point in their lives. Feedback from the group exit interview identified tangible targets for course revision or development should CasePREP have continued. As important, feedback also revealed a more general need for social support outside of class. These latter data are in agreement with research that indicates social networks, such as those comprised of friends and peers (Tullis and Grunert Kowalske 2021), are important in persisting in STEM and identifying as a scientist (Estrada et al. 2019).

Despite these limitations, the overall trend is very clear. As one of the longest-running NIGMS-supported PREPs, CasePREP provides a large single-institution dataset available for post-baccalaureate program evaluations. The CasePREP data demonstrate that the majority of Scholars pursued and attained terminal degrees necessary for careers in biomedical research. The data suggest that the US federal government and institutional investments made in these Scholars are economically and scientifically beneficial for multiple stakeholders. Relatively few CasePREP alumni have been lost to follow-up, testament to their persistence in careers in research and the utility of social media in tracking long-term outcomes of trainees (Lee et al. 2025).

CasePREP, while highly successful, is not unique among NIGMS-supported PREPs. CasePREP is one of more than 60 unique PREPs supported by NIGMS. Published program evaluations demonstrate that Scholars enter PhD or MD/PhD programs at high rates (from "well over half" (McGee, Saran, and Krulwich 2012) to "about 65%" (Hall, Mann, and Bender 2015) to "more than 80%" (Gazley et al. 2014) to 84.8% (Wright et al. 2024) to 86% (Schwartz et al. 2020) to 91%) (Hall et al. 2016; Schwartz et al. 2020) and that their attrition in these PhD programs is relatively low [4.9% (Hall et al. 2016) to 11% (Wright et al. 2024) to 23% (McGee, Saran, and Krulwich 2012)]. CasePREP outcomes for PhD or MD/PhD program matriculation (83%) and attrition (14.77%) fall within the range published by other PREPs.

The almost uniform success of these NIGMS-supported PREPs, based on matriculation and attrition outcomes, likely reflects a complex interplay between the design and implementation of this research-intense, one-year training program and the Scholars' motivations and determination to matriculate into a PhD or MD/PhD program. The latter point, in fact, reveals an important selection bias common across PREPs: the successful PREP Scholar applicant, regardless of previous academic performance or research experiences, can articulate or express the explicit intention to enter a PhD program after completion of PREP to become a scientist. PREP Scholars are highly motivated to attend graduate school, and for many, this post-baccalaureate program offered the opportunity for the Scholars to realize their academic and research potentials on par with more well-resourced undergraduates at research-intense institutions. For other Scholars, PREP offered an important transition between undergraduate studies and the rigors of independent graduate study. Surveys and interviews indicate that completion of PREP increased Scholars' confidence and readiness for graduate school and eventual careers in science (Gazley et al. 2014; Remich et al. 2016), and this confidence and readiness is reflected in the low PhD program attrition rates documented here and elsewhere for PREPs.

Despite the overwhelming success of PREP, NIGMS early expired the PREP Notice of Funding Opportunity (PAR-22-220) on January 30, 2025, and, citing "changes in NIH/HHS priorities," abruptly terminated the program by email on April 2, 2025. At the time of the termination email, CasePREP had a scored renewal application in the final stages of award notice. CasePREP's NIGMS support ended June 30, 2025. To date, NIGMS has not published a revised Notice of Funding Opportunity for a post-baccalaureate research education program or equivalent.

The loss of CasePREP has adverse effects on a variety of stakeholders, including CWRU, Cleveland, Ohio, aspiring scientists, PhD programs across the country, and the scientific community at large. The CasePREP renewal, had it been supported at the requested level, would have brought in ~$2.7 million dollars spent and taxed in the local, state, and federal economies. The five-year renewal would have supported an additional 30 CasePREP Scholars and would have partially supported two faculty and an administrator. The termination of the program removes a tangible, and, for some Scholars, necessary pathway to graduate school. For PhD programs, the absence of PREP may translate into fewer prepared applicants and high attrition for those who matriculate. The high attrition or lower PhD completion rates, in turn, will lower the return of federal funding investment in producing US scientists. For the potential Scholars, loss of PREP reverberates beyond graduate school admissions, impacting real opportunities for upward economic mobility currently realized for CasePREP alumni scientists in industry and senior positions in academia.

Hard to envision but important to quantify is the potential loss of science and scientific discovery associated with loss of future scientists. Similar to recent efforts that describe the potential negative impact of proposed NIH budget reductions (Azoulay et al. 2025), we attempted to describe the science that would have been lost had the CasePREP Scholars not trained in science or entered the scientific workforce. Based on the scientific literature co-authored by CasePREP Scholars, the absence of their foundational science would have impacted approximately 253K citations in three generations and more than 15M citations by five generations of a citation cascade. While these estimates are extreme in the assumption that the absence of the foundational science would directly eliminate downstream science, even a fraction of missed connections between the foundational science and downstream science has a meaningful and negative impact on timely discoveries and translation potential.

More sobering than the loss of citing science is the loss of the scientists themselves. The traditional pathway to a career in science is long in time spent in education and training, and longer yet for trainees whose pathway to science is not linear. NIH has been the main source of institutional- and individual-level support for undergraduate, graduate, and post-doctoral trainees in biomedical research. As of 2025, many of these training and career development grant awards and mechanisms have been terminated or disappeared (Liu et al. 2025; Ross 2025; Nienaber and Leeming 2025), including NIGMS's Undergraduate Research Training Initiative for Student Enhancement (U-RISE) (T34) (Health 2025i), Bridges to the Baccalaureate Training Program (B2B) (T34) (Health 2025a), Maximizing Access to Research Careers (MARC) (T34) (Health 2025e), Bridges to the Doctorate Research Training Program (T32) (Health 2025b), PREP (R25) (Health 2025f), the Initiative for Maximizing Student Development (IMSD) (T32) (Health 2025d), Graduate Research Training Initiative for Student Enhancement (G-RISE) (T32) (Health 2025c), and the Ruth L. Kirschstein NRSA Individual Predoctoral Fellowship to Promote Diversity in Health-Related Research (Parent F31-Diversity) (Health 2025g). All of the NIH predoctoral fellowships or supplements awarded to CasePREP alumni, with the exception of one F30, were associated with a diversity grant mechanism now expired or disappeared. To our knowledge, no active, individual-level fellowship among CasePREP alumni has been terminated; however, anecdotally at least two CasePREP alumni have reported their NRSA F31-D submissions administratively withdrawn prior to study section. Also, based on a recent LinkedIn search, one CasePREP alumna employed by NIH may have lost their job during the February 2025 reduction in force (Owermohle 2025; Travis et al. 2025). With severe budget cuts realized at NSF (Mervis 2025; Langin 2025) and changes made to HHMI (Wadman 2025a) and other private fellowships, it is not clear what funding mechanisms outside of NIH are or will be available to predoctoral or postdoctoral trainees from backgrounds uncommon in science. In parallel, anticipated budget cuts to NIH (Jalali and Hasgul 2025; Wadman 2025b) and other funding issues (Garisto 2025a) are threatening individual institution budgets, forcing most to consider smaller cohorts of trainees compared to past cohorts (Garisto 2025b). The perfect storm of unusual funding and political climates, regardless of diversity funding mechanism availability, are sure to produce fewer future US scientists of all backgrounds for years to come.

If NIGMS-supported PREP has been an experiment, the results show it is a huge success. Collectively, NIGMS PREPs have bridged many gaps between research talents from all walks of life and the unequal access to research experiences necessary to enter graduate training programs on the path to a career in biomedical research. Scientific advancements have greatly benefited from having researchers from different backgrounds and perspectives (Powell 2018; 'Science benefits from diversity'  2018; Hodapp and Brown 2018; Yang et al. 2022; AlShebli, Rahwan, and Woon 2018; Nielsen et al. 2017; Campbell et al. 2013). Losing NIGMS-supported PREPs, and the future scientists they nurtured, will have devastating effects on the scientific enterprise and society as a whole.

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**Table 1. CasePREP activities and syllabus, by academic term.** CasePREP activities and formal class syllabus shown here are based on the 2024-2025 cohort. In general, CasePREP Scholars were selected from a competitive application process between January and March or until the slots were filled. CasePREP generally began the first week of July and ended mid-to-late May. All Scholars were hired by CWRU as Research Technicians I, and Scholars were matched with research mentors within weeks of hire. Scholars met as a class with the directors on a weekly basis beginning in the summer. The fall and spring weekly meetings were formalized as a graded, one credit course. Grades were based on class participation, assignments outlined in the table, and completion of Scholars Hub, a custom database designed to capture Scholars' academic activities (e.g., departmental seminar attendance; professional development workshop attendance, classes taken and grades), research products (e.g., abstracts and manuscripts), and progress on graduate school applications. Outside the formal coursework, CasePREP Scholars, directors, and the administrator met for social activities. Overall, CasePREP was designed and scheduled to mimic the heavy courseload, research, and other academic expectations (e.g., journal club, conferences, and oral presentations) required of a first-year graduate student.

| **Summer** | **Fall** | **Spring** |
|---|---|---|
| Onboarding as a CWRU Research Technician 1 | Mentored research | Mentored research |
| CasePREP orientation | Resilience course (no credit hours) every other week | Resilience course (no credit hours) every other week |
| Three 2-day rotations | One 3-4 credit graduate-level course | One 3-4 credit graduate-level course |
| Mentor selection | Personal statements | Responsible Conduct of Research course |
| Social activities | Curriculum vitaes | Graduate school interviews |
| Weekly summer journal club given by graduate students, post-doctoral fellows, and | Selection of graduate programs for applications | Introduction to the primary scientific literature |

| | | |
|---|---|---|
| professors | | |
| Selection of fall semester class | Write and submit abstract for a national scientific conference | Making figures for presentations, manuscripts, grants |
| One-on-one meetings with directors | One-on-one meetings with directors | One-on-one meetings with directors |
| Establish or update LinkedIn account | Apply to at least 9 PhD or MD/PhD programs | Formal journal club |
| Mentored research | Present poster at national scientific conference | Introduction to NIH fellowships |
| | Individual development plans | Social activities |
| | Research oral presentations | Write a Specific Aims page |
| | Mock graduate school interviews with CWRU faculty | Mock study section |
| | Social activities | Research oral presentations |
| | | Select graduate program for fall matriculation |
| | | School of Medicine PREP Research Day presentations |
| | | Network with CasePREP alumni to prepare for transition to graduate school |

**Table 2. Resilience cohort group exit interview themes by sentiment.** CasePREP 2023-2024 Scholars were interviewed as a group by the resilience course facilitator. The transcript of the interview was used as input into Anthropic's Claude to identify themes by sentiment.

| Theme | Positive Feedback | Negative Feedback | Suggestions |
|---|---|---|---|
| Course content | Informative and useful for transitioning to graduate school | Too broad; not all content was relevant | More tailored content to specific student needs |
| Course Structure | Flexibility of topics, webinars, and discussions worked well | Content not always aligned with current challenges | Use surveys to adjust weekly topics |
| Application in Graduate Life | Provided valuable tools for mentorship, burnout prevention | Hard to implement without more social support | Follow-up on the implementation of learned strategies |
| Support | Supportive classroom environment; encouraged openness | Not all students had access to social support outside of class | Create more formal support networks in future courses |
| Relevance | Connected to personal experiences and real-time challenges | Topics felt too general at times | Personalize course topics based on student preferences |
| Barriers to implementation | Students valued resilience tools and communication strategies | Mental and emotional barriers prevent application | Provide ongoing support after the course |

**Figure 1. Home state of CasePREP Scholars.** US states and territories colored blue represent at least one CasePREP Scholar’s home state at the time of application to the program. The shade of blue proportion of Scholars residing in the state from least (light blue) to most (dark blue). Not shown: Alaska (grey), Hawaii (grey), and the US Virgin Islands (lighted blue).

**Figure 2. Distribution of Institutional Classifications from the Carnegie Classification of Institutions of Higher Education 2025.**

**Figure 3. Brief resilience scale results before and after a 13-week resilience course.** Six Scholars from the 2023-2024 cohort took the brief resilience scale (BRS) at the beginning of the Spring 2024 semester and at the end of the semester. The BRS is a self-administered, 6-item questionnaire designed and validated to assess the ability to bounce back or recover from stress. Respondents rate each of the following items on a Likert-like scale (1-5): I tend to bounce back quickly after hard times; I usually come through difficult times with little trouble; I tend to take a long time to get over set-backs in my life; it does not take me long to recover from a stressful event; It is hard for me to snap back when something bad happens; I have a hard time making it through stressful events. Scholars’ post-survey responses were compared to pre-survey responses to categorize responses as improved (black), unchanged (dashed), or worsened (gray) resiliency (x-axis). Data are expressed as percentages (y-axis).

**Figure 4. CasePREP Scholar research based on publication titles.** PubMed-index publication titles associated with CasePREP Scholars were parsed for 406/407 publications. A word cloud was generated based on the frequency of individual words identified in these titles. One publication was not associated with a parsable title. Publications included here were based on a PubMed search through September 2025.

**Figure 5. CasePREP Scholar scientific publications over time.** Plotted are the number of publications published by CasePREP Scholars (y-axis) by publication year (x-axis). Publications were identified through PubMed by CasePREP Scholar alumni names and include publications based on research prior to CasePREP, during CasePREP, and after CasePREP. PubMed indexed bioRxiv and medRxiv manuscripts are not included in this plot. As of the end of September 2025, 75/108 CasePREP Scholars had at least one PubMed indexed manuscript published in a peer-reviewed journal. The plot was generated by ggplot in R using geom_smooth (method = ”loess”, se = TRUE), which computes the regression line (dashed line) and 95% confidence interval (gray) for the total number of publications per year (red dots) over time.

**Figure 6. Estimated NIH investment in graduate training lost to attrition.** NIH investment, assumed at $50,000/year/graduate student is shown for two (stippled) and three (solid black) years of graduate studies (x-axis) for trainees lost to attrition at varying attrition rates (y-axis). CasePREP attrition rate is the actual rate (14.77%) based on 88 Scholars who entered graduate school as of September 2025. The other attrition rates are applied to a hypothetical cohort of 88 first-year graduate students who did not participate in CasePREP. X-axis represents United States dollars in millions.

**Figure 7. Return of investment in CasePREP.** Return of investment in CasePREP (y-axis, expressed as %) is estimated, assuming a Scholar attrition rate of 15% compared to various attrition rates for graduate students who did not participate in CasePREP. NIH investment in graduate students is assumed to be $50,000 USD/trainee/year for 1) two years (stippled) and 2) three years (solid black). Net program benefits are estimated as the difference between NIH investment lost to attrition for a hypothetical cohort of 88 graduate students (varying attrition rates) and a hypothetical cohort of 88 CasePREP Scholars (15% attrition). Program costs were

estimated as the actual total NIH funds awarded to Case Western Reserve University School of Medicine expressed as a per Scholar cost for the 88 Scholars who entered a PhD or MD/PhD program after CasePREP.

**Figure 8. Estimated 2024 annual salaries by terminal degree.** We estimated 2024 annual salaries for 63 CasePREP Scholars who had a known salaried position as of the end of 2024. We estimated salaries based on position descriptions posted on LinkedIn and other social media and salary estimated from GlassDoor.com and similar resources (see Methods and Materials). Average salaries are plotted (x-axis) by terminal degree (y-axis), which included Bachelor’s degrees (n=4), Master’s degrees (n=6), PhDs with positions in academia (n=20), PhDs with positions in industry (n=20), dual degree MDs such as MD/PhD, MD/MPH, and MD/MS/JD (n=5), and MDs or DOs (n=6). Not shown are one MBA and one PharmD/MS. Shown in the middle of each salary average is the average number of years since terminal degree (or for Bachelor’s degree, since CasePREP) and the range.

**Figure 9. CasePREP outcomes for all Scholars.** CasePREP outcomes, as of September 2025, are shown for all Scholars. Data are visualized as a flow diagram using SanKeyMATIC.

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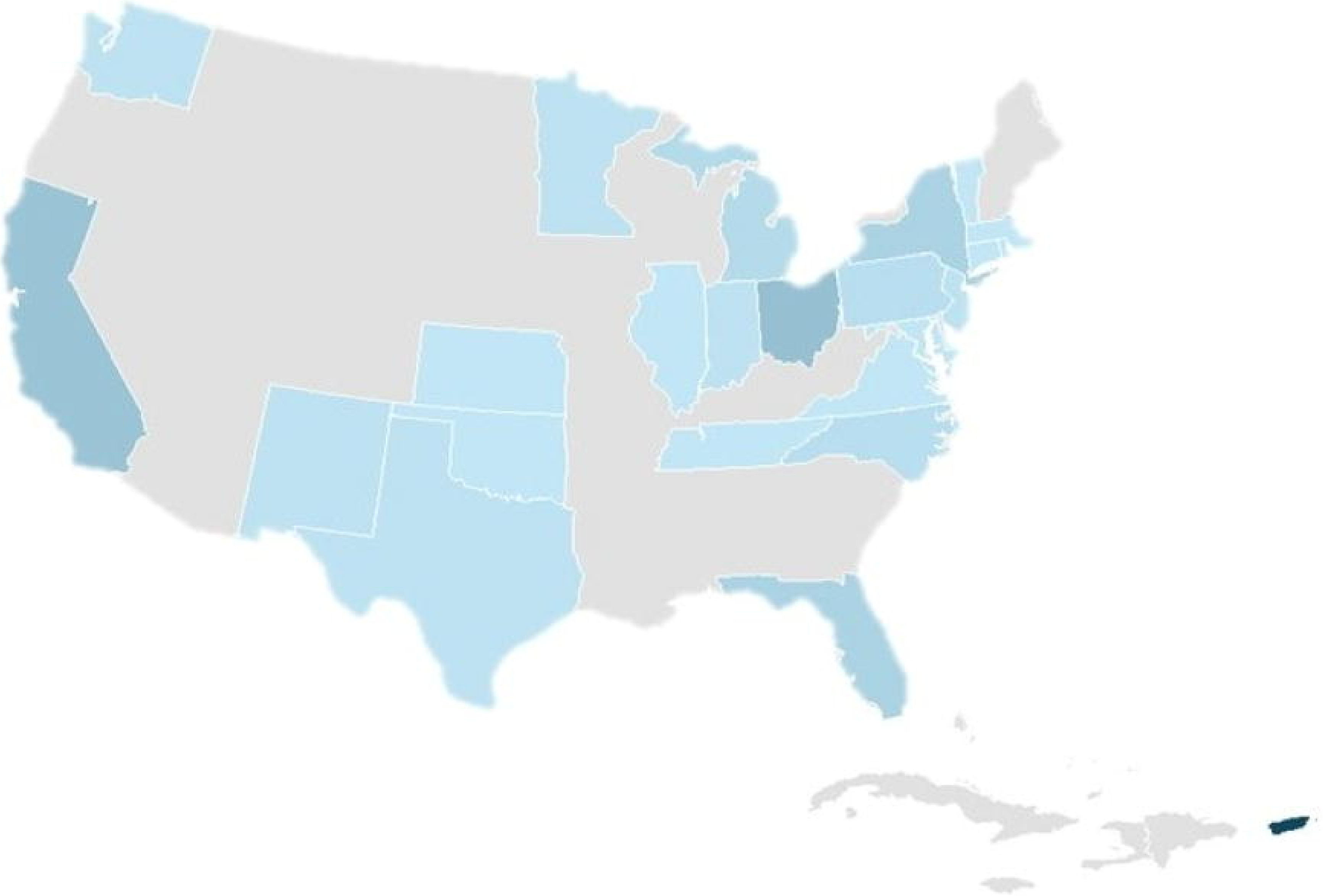

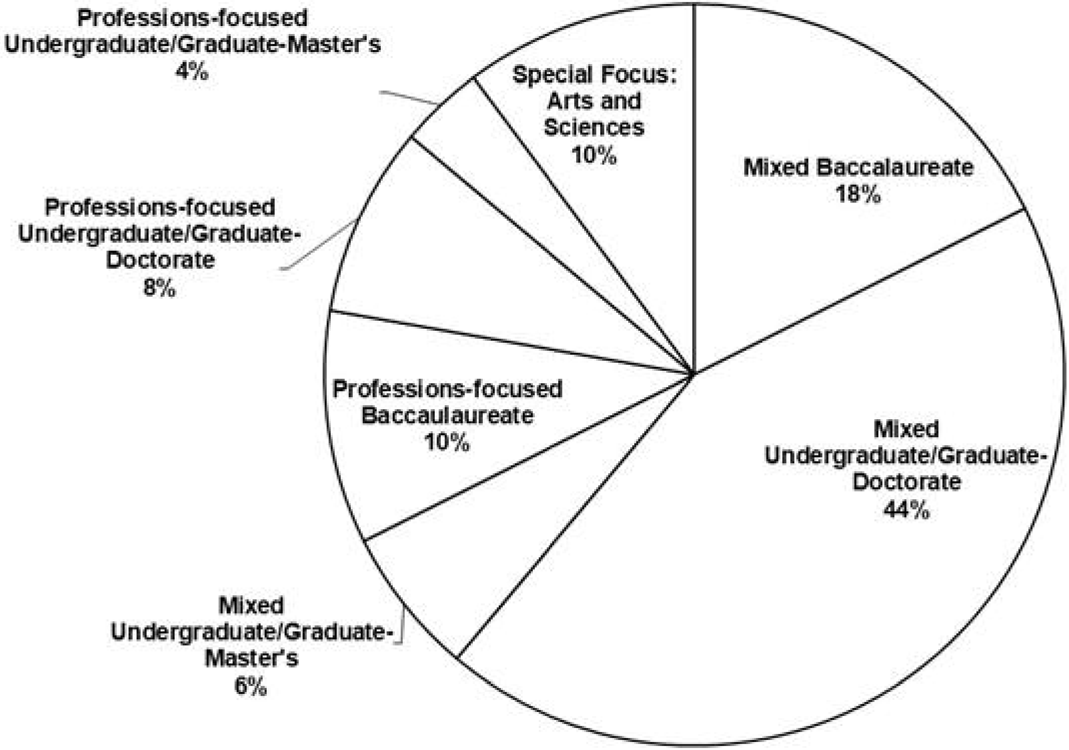
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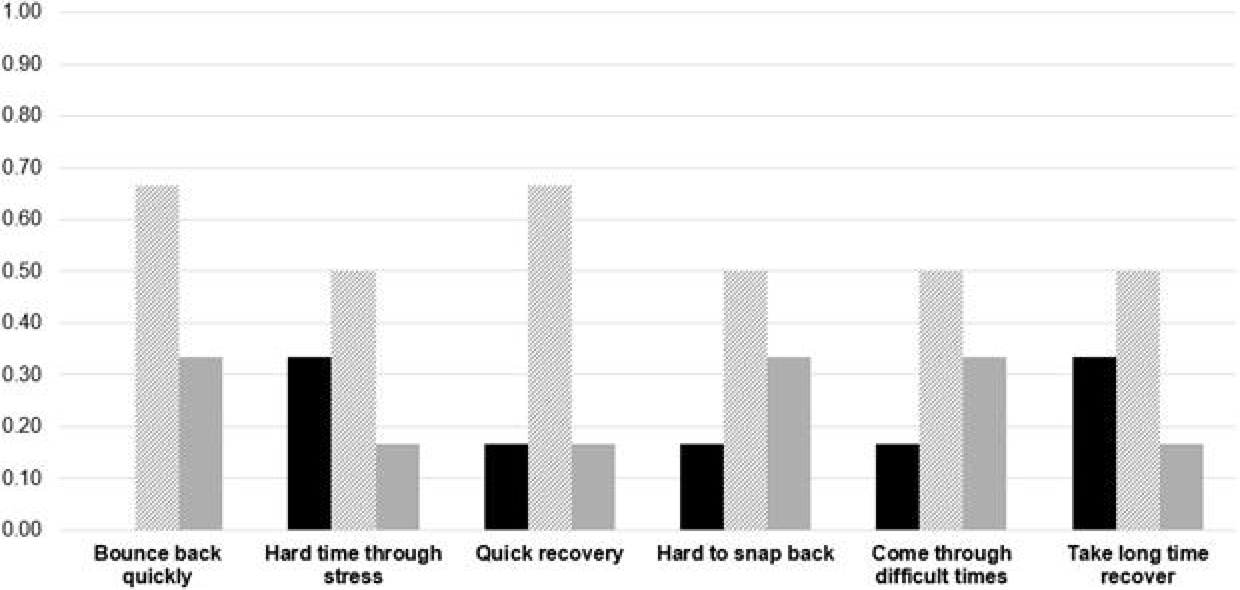
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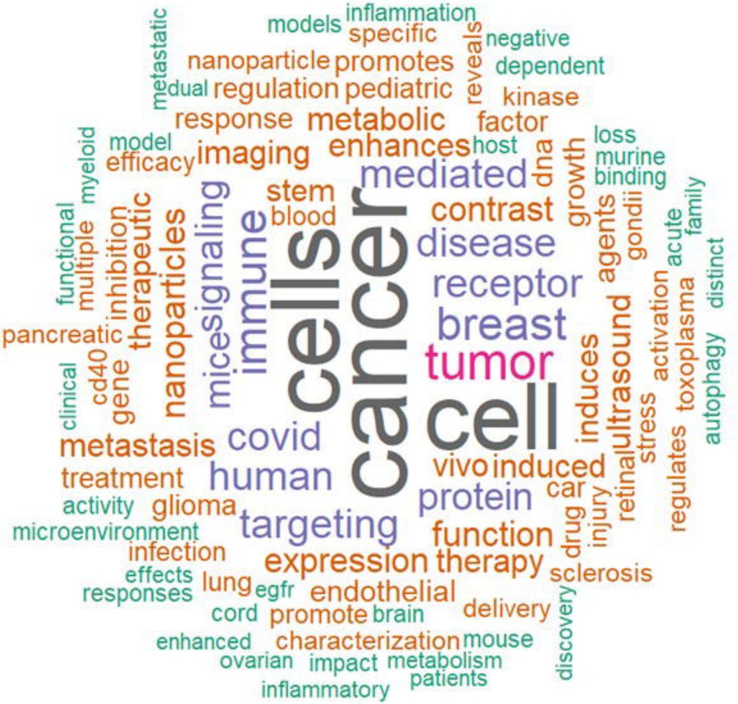
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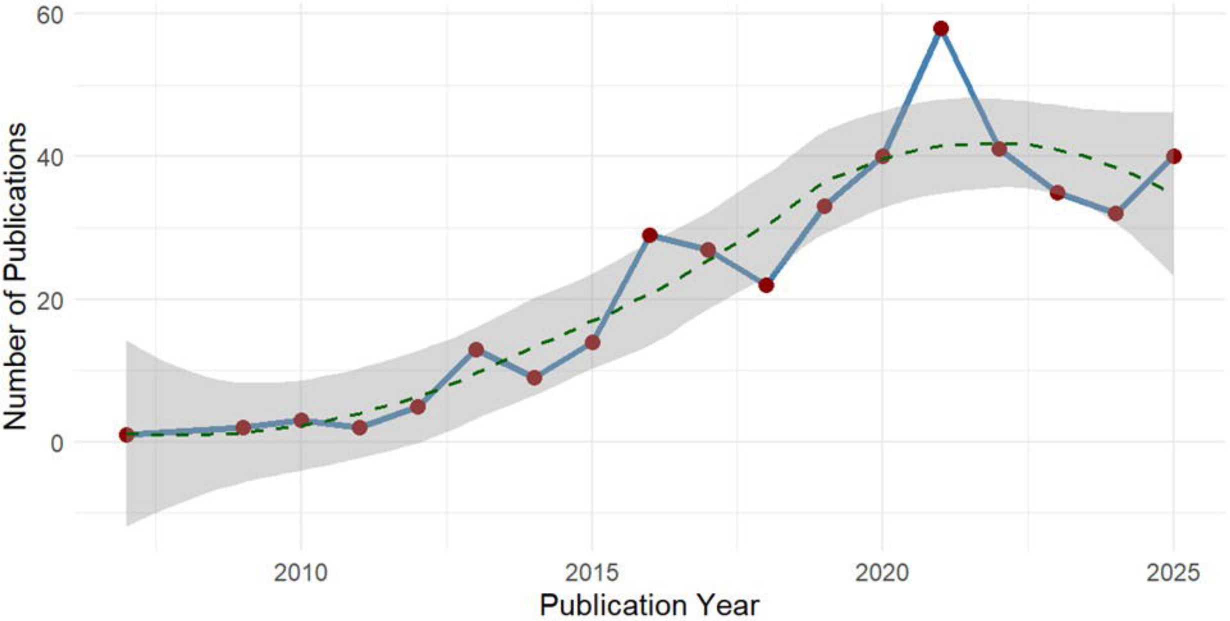
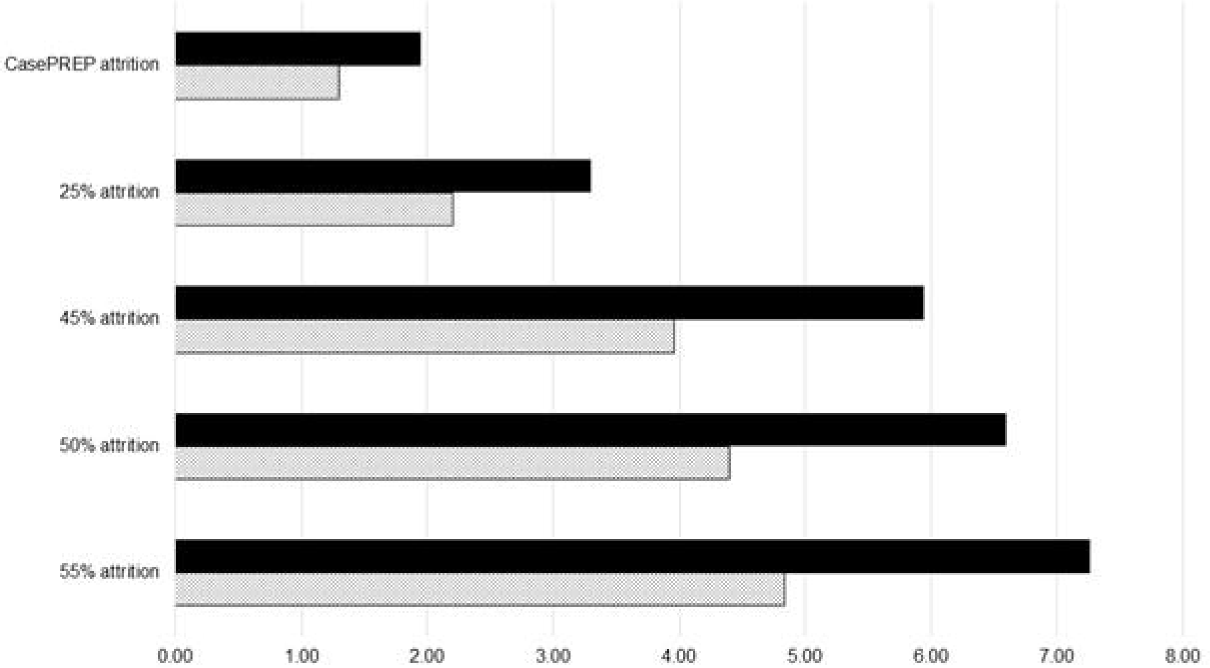
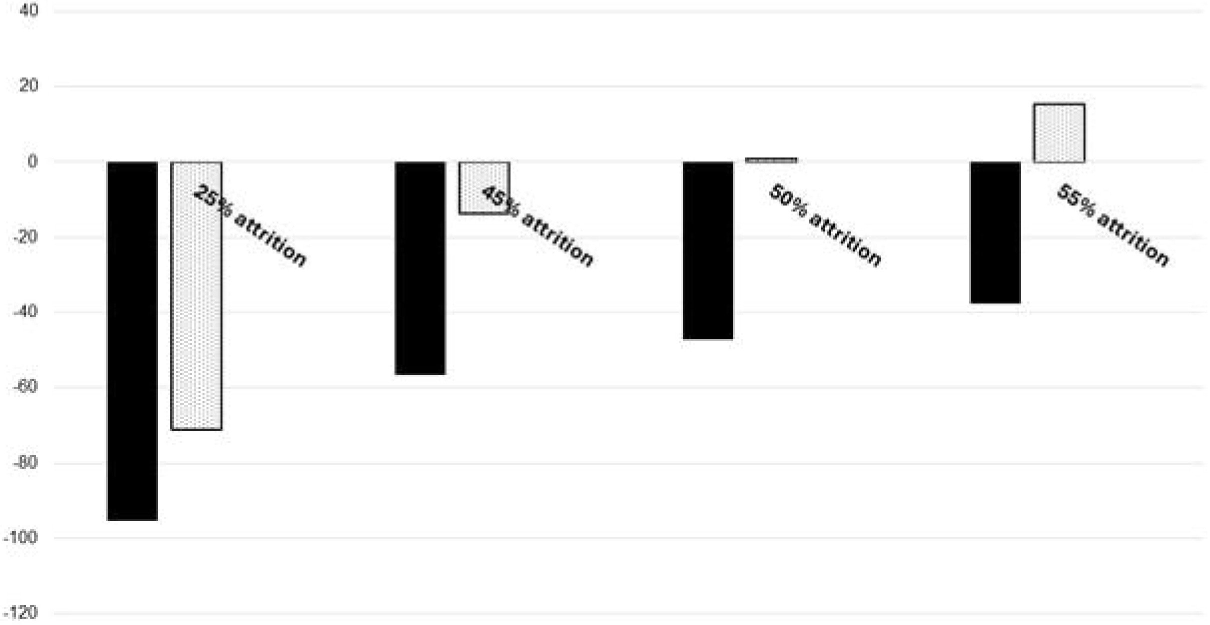
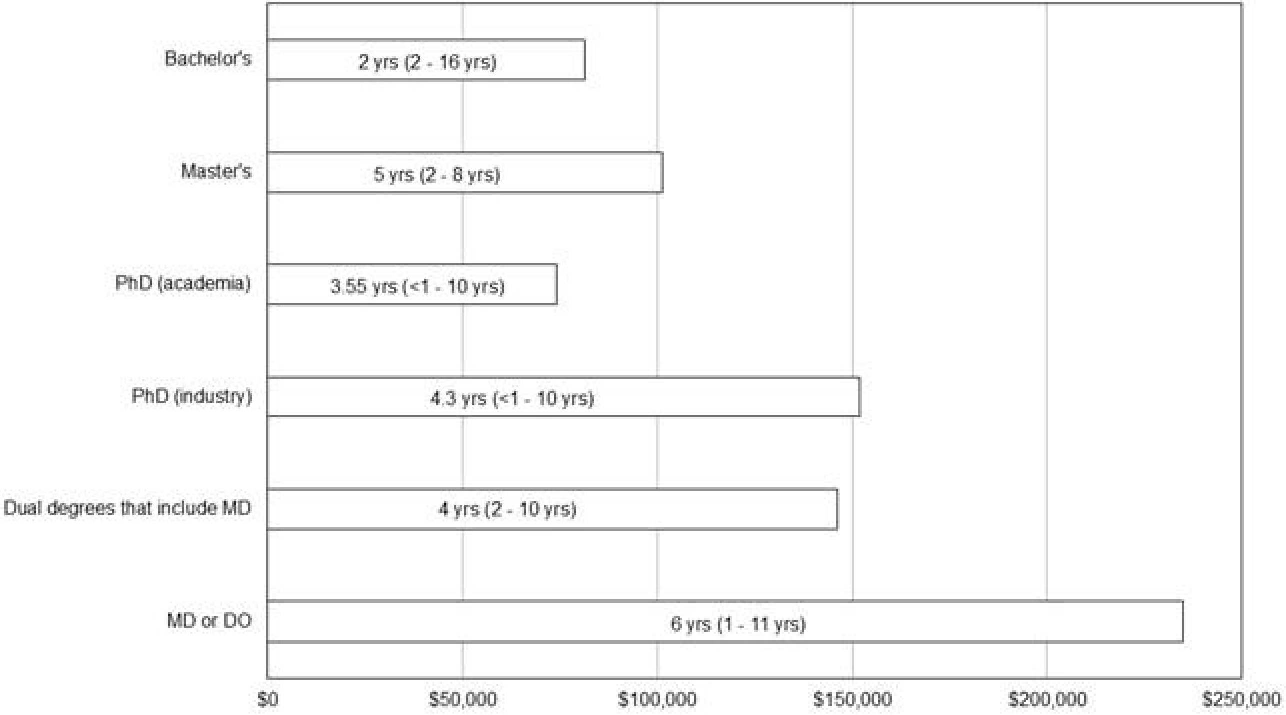

60
40
20
0
Number of Publications
2010
2015
2020
2025
Publication Year


CasePREP attrition
25% attrition
45% attrition
50% attrition
55% attrition
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00


40
20
0
-20
-40
-60
-80
-100
-120
25% attrition
45% attrition
50% attrition
55% attrition


Bachelor's
2 yrs (2 - 16 yrs)
Master's
5 yrs (2 - 8 yrs)
PhD (academia)
3.55 yrs (<1 - 10 yrs)
PhD (industry)
4.3 yrs (<1 - 10 yrs)
Dual degrees that include MD
4 yrs (2 - 10 yrs)
MD or DO
6 yrs (1 - 11 yrs)
$0
$50,000
$100,000
$150,000
$200,000
$250,000

Entered CasePREP: 108
Completed CasePREP: 106
Entered PhD program: 83
Completed PhD program: 46
Current PhD trainee: 24
Did not complete PhD: 12
Master's degree: 8
Deferred: 1
Entered workforce: 9
Entered other graduate program: 13
Did not complete CasePREP: 2
Entered PharmD program: 3
Completed PharmD program: 1
Entered MD or DO program: 11
Completed MD or DO program: 9
Entered MD/PhD program: 6
Current MD/PhD trainee: 3
Completed MD/PhD program: 2
MD: 1

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